A Comparative Analysis of Bicycle Lanes Versus Wide Curb Lanes: Final Report

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16. Abstract

This report is a comparative analysis of bicycle lanes (BLs) versus wide curb lanes (WCLs). The primary analysis was based on videotapes of almost 4,600 bicyclists (2,700 riding in BLs and 1,900 in WCLs) in the cities of Santa Barbara, CA, Gainesville, FL, and Austin, TX, as the bicyclists approached and rode through eight BL and eight WCL intersections with varying speed and traffic conditions. The intent was to videotape bicyclists who regularly ride in traffic. The videotapes were coded to learn about operational characteristics (e.g., intersection approach position and subsequent maneuvers) and conflicts with motor vehicles, other bicycles, or pedestrians. A conflict was defined as an interaction between a bicycle and motor vehicle, pedestrian, or other bicycle such that at least one of the parties had to change speed or direction to avoid the other. Both bicyclist and motorist maneuvers in conflict situations were coded and analyzed. This covered maneuvers such as a bicyclist moving incorrectly from the bicycle lane into the traffic lane prior to making a left turn, or conversely, a motor vehicle passing a bicyclist and then abruptly turning right across its path. Bicyclist experience data were also collected separately from the videotaping at each of the 16 data collection sites in each city through use of a short oral survey. Slightly more than 2,900 surveys were completed. These data were analyzed to learn about the age, riding habits, and experience levels of the bicyclists riding through these intersections. Bicycle-motor vehicle crash data were also analyzed to determine if there were parallels to the videotape data.

In addition to this final report, there is a separate report (FHWA-RD-99-035) containing a synopsis of the key findings of the final report and recommended countermeasures, as well as a guidebook (FHWA-RD-99-036) about innovative bicycle accommodations.

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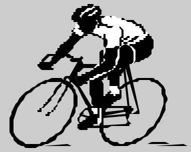

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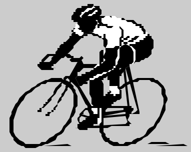


Background

A number of recent events renders a study of bicycle facilities as appropriate and timely. The passage of the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) legislation meant a variety of funds could be more readily used by local and state officials to plan and build such facilities. Indications are that many governments and agencies have taken advantage of the opportunity. Publication of the National Bicycling and Walking Study in 1994 with the U.S. Department of Transportation (USDOT) goals of doubling the percentage of trips made by bicycling and walking and simultaneously reducing by 10 percent the number of bicyclists and pedestrians injured or killed in traffic crashes adds emphasis to the need to accommodate non-motorists with well-designed facilities. User survey respondents have clearly stated that more facilities are desired and will increase the amount of travel by bicycle.

In addition to the recent activities mentioned above, during the past 20 years bicycle facilities have been planned and implemented in communities now considered as pro-bicycling, including Seattle, WA; Davis and Palo Alto, CA; Madison, WI; Eugene and Corvallis, OR; Boulder, CO; Gainesville, FL; Tucson, AZ; and others. These communities tend to have a local bicycle coordinator and bicycling advisory committee in place. Not all of the implemented facilities have been ideally constructed. However, what has tended to occur in all of these communities is that motorists have adapted to bicyclists where bicycle facilities have been implemented, and most facilities appear to function effectively, although not without some problems. What has not been done and reported to the bicycling and traffic engineering community is a thorough evaluation of the various kinds of facilities in communities like these.

Given the information presented above, considerable effort was devoted to deciding what kinds of bicycle facilities should be evaluated in this project. A long-standing issue in the bicycling community centers on whether bicycle lanes or wide curb lanes are preferable. A bicycle lane (BL) is a portion of a roadway that has been designated by striping and pavement markings for the preferential or exclusive use of bicyclists (figure 1). BL width is normally in the range of 1.2 to 1.8 m. A wide curb lane (WCL) is the lane nearest the curb that is wider than a standard lane and provides extra space so that the lane may be shared by motor vehicles and bicycles (figure 2). Thus, WCLs

Figure 1. Typical bike lane.

may be present on normal two-lane roadways or on multilane roadways. A desirable width for WCLs is 4.3 m. Lanes wider than 4.6 m sometimes result in the operation of two motor vehicles side by side. Many bicyclists report feeling safer when riding on BLs, while BL opponents venture that these facilities make it difficult for bicyclists to handle turning maneuvers at intersections, especially left turns. WCL advocates believe that these wider lanes encourage cyclists to operate more like motor vehicles and thus lead to more correct maneuvering at intersections. Both perspectives have merit and should be addressed in any evaluation of these facilities. Because a WCL is a wider-than-normal traffic lane that is shared with motor vehicles, some do not refer to this layout as a bicycle facility. However, for purposes of this study, *both* BLs and WCLs will be referred to as bicycle facilities.

The debate over whether BLs or WCLs are preferable has been heated for many years and is not unlike the seat belts versus air bags dichotomy that prevented a concerted approach to the promotion of occupant restraints in the United States in the 1970s and 1980s. While both BLs and WCLs are acceptable facilities in many locations, the debate has sometimes forced decision makers to choose which facility type they prefer, to the exclusion of the other. More bicycle facilities might be in place in this country except for this long-standing division of opinion. Because of the interest in BLs and WCLs, it was decided to make these facilities the focus of this project, with an emphasis on operations and interactions between bicyclists and motorists at intersections.

Objective and Scope

The primary objective of the current study was a comparative analysis of BLs versus WCLs. Bicyclists riding in either a BL or WCL were videotaped as they proceeded through BL and WCL intersections with varying speed and traffic conditions in three U.S. cities. The videotapes were coded to learn about operational and safety characteristics. Operational characteristics pertained to how bicyclists maneuvered through the sites, while safety characteristics pertained to conflicts with motor vehicles, other bicycles, or pedestrians. A conflict was defined as an interaction between a bicycle and motor vehicle, pedestrian, or other bicycle such that at least one of the parties had to change speed or direction to avoid the other. Exposure/experience data were also collected separately from the videotaping at each of the data collection sites in each city through use of a short oral survey. Information was obtained about the age, gender, race, helmet use, levels of experience, etc., of the bicyclists riding through these intersections.

A secondary study objective was to develop a guidebook of current *innovative* bicycling activities, with a primary focus on intersection treatments that pertained to BLs and WCLs. The innovative treatment "shopping list" included advance stop bars (often called bike boxes) where bicycles are allowed to proceed ahead of motor vehicle traffic at an intersection; painting a modified version of the bicycle logo near the curb in a WCL to alert drivers that bicycles would be operating in this space; colored

Figure 2. Typical wide curb lane.

pavement designating the appropriate path for the bicycle through an intersection; traffic calming measures like diagonal diverters and speed humps with "slots" in the pavement for bikes and buses; bicycle traffic signals; combination bus/bike lanes; different techniques for separating bike lanes; and others. The Bicycle Federation of America (BFA) was responsible for locating the relevant examples and developing appropriate descriptions. This guidebook is one of the final products of this contract.

Brief Literature Review

The National Bicycling and Walking Study (1994) established USDOT goals of doubling the percentage of trips made by bicycling and walking, while simultaneously reducing the number of bicyclists and pedestrians injured or killed in traffic crashes by 10 percent. To realize these goals, our transportation system needs better ways to accommodate bicycling and walking. The 1991 ISTEA allowed cities and States to spend Federal transportation funds on facilities for bicycling and walking. Local

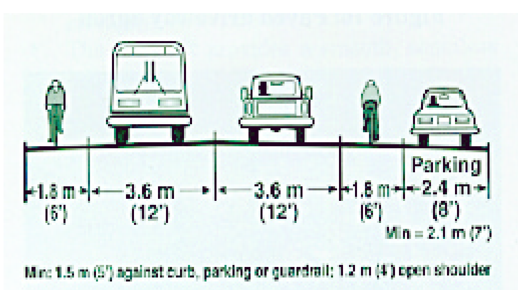


Figure 3. Oregon bike lane standards.
Source: Oregon Bicycle and Pedestrian Plan, 1995

bicycle planners can choose among conventional roadway treatments such as BLs and WCLs, and more innovative treatments such as modern roundabouts and advanced stop bars (popularly referred to as bike boxes in the United States).

Bicycle lanes

A *bicycle lane* is a section of the roadway that is delineated from the adjacent motor vehicle travel lane by a stripe. BLs are usually along the right edge of the roadway, but may be designated to the left of parking or right-turn lanes. Recommended widths for bicycle lanes (figure 3) are generally 1.2 to 1.8 m

(see, for example, North Carolina DOT, 1994; New Jersey DOT, 1995; Oregon DOT, 1995). A Dutch design manual (C.R.O.W., 1994) suggests 2.0 m so that bicyclists can ride side-by-side, and another Dutch study (Botma and Mulder, 1993) calls for a width of 2.5 m when the 1-hour peak volume exceeds 150 bicycles to allow bicyclists to pass one another. In a nationwide survey of U.S. cyclists taken many years ago, 85 percent considered BLs wider than 1.8 m to be adequate; only 41 percent considered BLs narrower than 1.5 m to be adequate (Kroll and Sommer, 1976).

Ninety-three percent of U.S. cyclists using BLs thought the street was safer with the lanes than without them, although there was no conclusive evidence that they actually improved cyclist safety (Kroll and Sommer, 1976). Two other studies credited BLs with reducing bicycle-motor vehicle crashes by more than half in Corvallis, Oregon, and by two-thirds in Eugene, Oregon (Ronkin, no date; City of Eugene, 1980). The installation of BLs along a one-way arterial pair in Madison, Wisconsin, was associated with a significant increase in the number of crashes associated with turning movements; however, crashes decreased sharply after the first year of operation (Smith and Walsh, 1988).

A manual prepared for the Federal Highway Administration (FHWA) uses various factors to make recommendations for roadway design treatments for accommodating bicyclists. The factors include definitions of design bicyclists, type of roadway, traffic volume, average motor vehicle operating speeds, traffic mix, on-street parking, sight distance, and number of intersections and entrances. BLs are often recommended when most bicyclists on the route are less experienced (Wilkinson, Clarke, Epperson, and Knoblauch, 1994).

In Denmark, roadway stretches with BLs or bicycle paths tended to have a lower frequency of crashes involving cyclist casualties than stretches without lanes or paths (Herrstedt et. al., 1994). Another evaluation of BLs in Denmark found no change in the number of overall crashes or bicycle-motor vehicle crashes at signalized junctions, but did find an increase in the number of bicycle-motor vehicle crashes at priority junctions (unsignalized junctions, usually signed, where one roadway has priority over the other). There was also a reduction in all crashes on stretches (the sections of roadway between intersections) (Jensen, 1997).

The presence of a stripe separating bicyclists and motorists (as with a BL or paved shoulder) has been shown to result in fewer erratic driver maneuvers, more predictable bicyclist riding behavior, and enhanced comfort levels for both groups of users (Harkey and Stewart, 1997; Kroll and Ramey, 1977; McHenry and Wallace, 1985). The principal findings from the 1997 study of bicyclists riding in midblock situations by Harkey and Stewart for the Florida DOT were the following:

- The separation distance between bicyclists and motorists was about 1.8 m and varied only a small amount by facility type (BLs, WCLs, and paved shoulders).
- The distance between the bicyclist and the edge of the roadway was considerably greater on BL and paved shoulder facilities (0.8 m) than on WCLs (0.4 m).
- Motor vehicles moved about 0.4 m further to the left when passing a bicyclist on WCLs compared with BL and paved shoulder facilities.
- Motor vehicle encroachment into the adjacent lane to the left when passing a bicycle was much greater on WCLs (22.3 percent) than on BL (8.9 percent) and paved shoulder facilities (3.4 percent).
- For a BL facility, the change in lateral position of the motor vehicle when passing a bicycle was approximately 0.3 m regardless of BL width.

Wide curb lanes

Wide curb lanes can accommodate both bicyclists and motorists and allow sufficient room for passing. These are sometimes designated when right-of-way constraints preclude the installation of "full width" BLs. WCLs should be 4.0 to 4.6 m wide (figure 4) to provide enough width for lane sharing but not so much width that motorists form two lanes at intersections (McHenry and Wallace, 1985). Wilkinson et al. (1994) recommend WCLs in many kinds of roadway situations where most bicyclists are experienced riders. The Harkey and Stewart study (1997) performed for the Florida DOT showed that motorists encroach into the adjacent lane of traffic significantly more often when WCLs are used as compared with BLs.

At present there appears to be a trend toward more use of BLs at the State and local levels, perhaps due to preferences cited by bicyclists. (See, for example, a statement in the *Florida Bicycle Facilities Planning and Design Manual* (Florida DOT, 1995) that WCLs should be used as a last resort because "only five percent of bicyclists feel comfortable using these facilities.") On the other hand, the North Carolina DOT (1994) refers to a 1970s FHWA publication to list principal problems with BL applications in its bicycle facilities planning and design guidelines, including: (1) provision of inadequate lane width or use of unrideable street surface as the BL area, (2) abrupt termination of lanes at hazard or constraint situations, creating a facility that leads bicyclists to a trap, as well as transitions that force awkward bicyclist movements at other termination points, (3) use of non-standard and poorly visible lane demarcation signs and markings that create uncertainties in motorist and bicyclist understanding of lane presence and purpose, (4) lane configuration and lane use ordinances that prevent the bicyclist from establishing proper position with respect to motor vehicle traffic at intersections, as well as for mid-block turns into driveways, and (5) lane use ordinances that conflict with reasonable bicyclist desires to leave the lane in order to avoid road hazards or to overtake other bicyclists, motor vehicles, or pedes- trians occupying the bike lane.

Other facilities

A *combined bus and bike lane* in Toronto was found to increase bicycle traffic and lower accident rates. More than 75 percent of riders felt safer riding along the new bus and bike lane (Egan, 1992). Combined bus/bike lanes should be 3.1 to 3.7 m wide (Harrison, Hall, and Harland, 1989). With bus/bike lanes, the potential exists for conflicts between buses and bikes at the crossing points. One design places a bicycle lane to the right of the through traffic lanes and to the left of the bus and right-turn lane. This allows bicyclists to ride without leap-frogging past stopped buses (Berchem and Somerfeld, 1985).

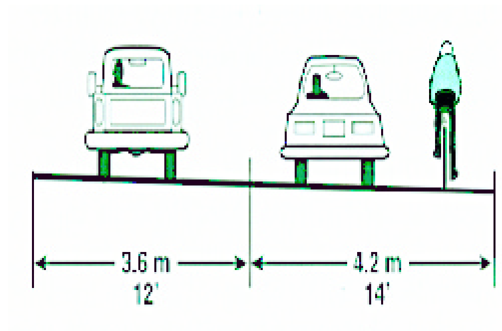


Figure 4. Oregon wide curb lane standards.
Source: Oregon Bicycle and Pedestrian Plan, 1995

Other Danish designs are aimed at reducing conflicts between bicyclists and bus passengers due to the high incidence of crashes in bus stop areas. These designs include: (1) *a pedestrian crossing combined with profiled markings* (figure 5); (2) *a profiled marking on the offside of the bicycle path*; and (3) *a painted pattern with a visual brake*. The intent was to use pavement markings to highlight the conflict area at bus stops and move bicyclists away from the passengers alighting from buses. The proportion of cyclists who wait for bus passengers to cross the bicycle path did not change with any of the designs.

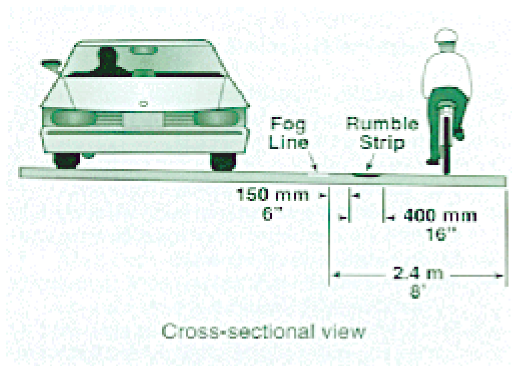


Figure 6. Oregon rumble strip.
Source: Oregon Bicycle and Pedestrian Plan, 1995

All three designs reduced the speed of cyclists when there was a bus at the bus stop. The distance from where cyclists first reacted to a bus to the nearest conflict point increased. The number of serious conflicts decreased with the painted pattern (Herrstedt, 1994).

The expected number of bicycle-motor vehicle crashes is much lower when bicyclists ride along *paved highway shoulders* than when bicyclists and motorists share the travel lanes (Khan and Bacchus, 1995). Operationally it has been shown that paved shoulders essentially function like BLs with respect to bicycle and motor vehicle interactions (i.e., the stripe separating bicyclists from motorists results in a lower risk environment for both modes of travel (Harkey and Stewart, 1997).

One potential hazard is that an inattentive or sleepy driver may drift off the roadway onto the shoulder and strike a bicyclist riding on the shoulder. Although there is considerable debate regarding the most effective design, a *shoulder rumble strip* (figure 6) is an efficient device to waken drivers who are drifting off the roadway (Garder, 1995). On highways with posted

Figure 5. Profiled marking at a bus stop to separate bicyclists from bus passengers.
Source: Safety of Cyclists in Urban Areas, 1994

speeds of less than 100 km/h, a minimum width of 1.5 m of paved shoulder is sufficient space to accommodate both a rumble strip and bicyclist travel (Khan and Bacchus, 1995).

In the Netherlands, separate *bicycle paths* are recommended when motor vehicle speeds exceed 50 km/h or when traffic volumes exceed 1,200 vehicles per hour. One-way cycle paths should be at least 1.8 m wide, and two-way cycle paths should be 2.8 m wide (Diepens and Okkema Traffic Consultants, 1995). In an earlier survey of U.S. cyclists, bike paths were rated as being safer than bike lanes, and most thought that paths wider than 2.8 m were "good" (Kroll and Sommer, 1976).

Intersection treatments

Intersections and *intersection-related locations* account for 50 to 70 percent of bicycle-motor vehicle crashes (Hunter, Stutts, Pein, and Cox, 1996). Countermeasures such as *grade separation* can be adopted to reduce intersection conflicts between bicycles and motor vehicles. More than 50 interchanges

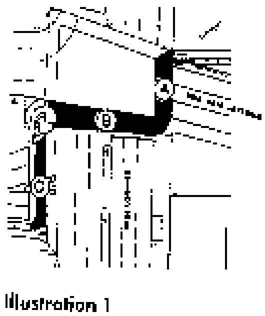


Figure 8. Colored bicycle crossing in Montreal
Source: Pronovost and Lusignan, 1996

in Beijing, China, provide for grade separation between bicyclists and motor vehicles (Liu, Shen, and Ren, 1993; Burden, Wallwork, and Guttenplan, 1994).

Figure 9. A European raised and painted bike path (crossing).
Source: Oregon Bicycle and Pedestrian Plan, 1995

Grade separation is expensive, though, and thus lower cost, at-grade treatments are more widely used. For example, bicycle path crossings of roadways can be offset away from the intersection to enhance bicyclists' view of motorists (NCHRP, 1976). On one street in Cupertino, California, a BL stripe was dashed to guide cyclists riding in the BL (next to the curb) to the left of right-turning vehicles (Grigg, no date). The Florida DOT (1995) is one of a number of State DOTs recommending that BLs be discontinued or dashed in advance of an intersection, so that bicyclists and motorists can merge (figure 7). Right-angle bicycle crossings with good sight lines are recommended at intersections.

At five intersections in Montreal, *colored bicycle crossings* were installed (figure 8), with the pavement colored blue at bicycle path crossing points. After the markings were painted, bicyclists were more likely to obey stop signs and to stay on designated cycle path crossings. Improved bicyclist behavior led to a decline in the level of conflict between cyclists and motorists (Pronovost and Lusginan, 1996). In Denmark, the *marking of bicycle travel paths (raised overpasses)* at

Figure 7. BL dashed to intersection.

signalized junctions resulted in 36 percent fewer accidents with motor vehicles and 57 percent fewer cyclists who were killed or severely injured (Jensen, 1997). Some of these crossings also used blue color on the pavement.

A *raised and painted bicycle path* (*crossing)* (figure 9) introduced at 44 intersections in Gothenburg, Sweden, reduced motor vehicle speeds (by 35 to 40 percent for right-turning motor vehicles) and increased cyclist speeds (by 10 to 15 percent). The safety improvement was estimated by using a quantitative model and by surveying bicyclists and experts. The model estimated the combined effect of lower motorist speeds and higher bicyclist speeds to be a 10 percent reduction in the number of bicycle-motor vehicle crashes. Bicyclists perceived a 20 percent improvement in safety after the bicycle path was raised and painted. Experts estimated a 30 percent improvement in safety. However, the authors suggested that the total numbers of crashes should be expected to increase due to a 50 percent increase in bicyclists using the improved crossings (Leden, 1997). A follow-on paper using a Bayesian approach for combining the results of the model and surveys estimated a risk reduction of approximately 30 percent attributable to the raised and painted crossing (Gårder, Leden, and Pulkkinen, 1998).

A different report based on a review of the literature, interviews with bicyclists, and expert opinion concluded that the crash risk would increase by about 40 percent when a bicycle path is added at a signalized intersection (Leden, Gårder, and Thedéen, 1993).

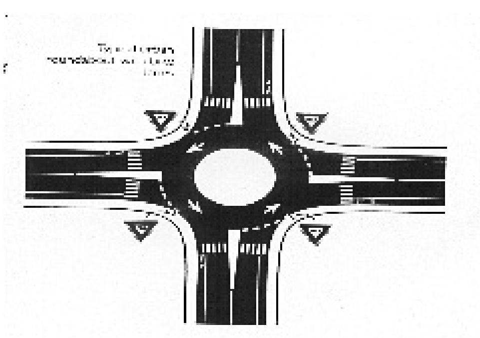


Figure 11. Modern roundabout.
Source: Innovative Bicycle Accommodations, in press

Profiled pavement marking aimed at reducing the lateral distance between motorists and cyclists and increasing attentiveness between bicyclists and motorists changed motorist and cyclist behavior at T-intersections and four-way intersections in Denmark (figure 10). Profiled markings were placed to guide approaching cyclists closer to the travel lanes. At the intersection, the cyclists were guided away from the travel lanes. More motorists adapted their speeds to the cyclists' speeds and stayed behind the stop line. Motorists were less likely to turn right in front of cyclists. At T-intersections, cyclists became alert earlier (Herrstedt et al., 1994).

Many bicycle-motor vehicle crashes at *roundabouts* occur when motorists cut in front of bicyclists or fail to yield the right-of-way. Small roundabouts with flared entry roads are the most dangerous design, whereas large roundabouts are the most feared by bicyclists. Crash rates for bicyclists at roundabouts in the United Kingdom are two to three times higher than those experienced by bicyclists at traffic signal-controlled intersections. Mini-roundabouts have a much better crash record, similar to that of four-way traffic, signal-controlled intersections. Lane markings, warning signs, sharper entry angles, and visibility improvements have helped reduce bicyclist crashes in roundabouts (figure 11). Smaller roundabouts, where motorists cannot overtake bicyclists, are recommended (Allott and Lomax, 1993; Balsiger, 1995). In a comparison of Swedish, Danish, and Dutch roundabouts, a separate cycle path with an

Figure 10. T-intersection marking in Denmark.
Source: Safety of Cyclists in Urban Areas, 1994

ordinary cycle crossing was found to be the safest design when motor vehicle traffic flows were large, compared with a cycle lane within the roundabout or no specific bicycle facility at all (Brüde and Larsson, 1996). Results were based on observed versus expected crashes, with expected crashes obtained from a predictive model. The authors noted that data were limited. A roundabout on the University of California at Davis campus allows five times as many cyclists to pass through, compared with when the intersection was controlled by stop signs, and bicycle crashes that result in injury

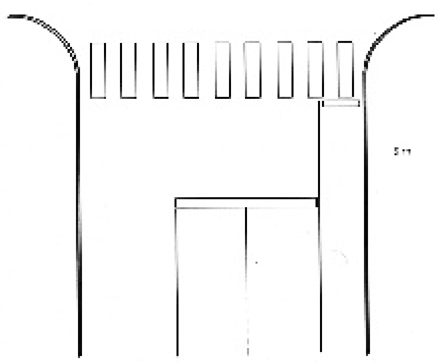


Figure 13. Recessed stop line.
Source: Safety of Cyclists in Urban Areas, 1994

are rare (Burden, Wallwork, and Guttenplan, 1994).

On roads with marked BLs, an *advanced stop line* (ASL) or *bike box* may be placed in the BL at a signalized intersection. The bike box is placed in front of the motor vehicle stop line to give bicyclists a space to wait in front of motorists and to allow them to pass through first when the green phase starts. Being in the box makes bicyclists more visible to motorists and can reduce conflicts with turning motor vehicles (figure 12). Under a single-signal design, one traffic signal is placed at the box. With a two-signal design, used in the United Kingdom, motorists are held by a red signal, while a special green signal directs bicyclists ahead to the box (U.K. Department of Transport, 1993; Zegeer et al., 1994).

Bike boxes have worked successfully on roads in the United Kingdom with up to 1,000 vehicles per hour passing through the intersection. Wheeler (1995) and Wheeler et al. (1993) monitored schemes at nine intersections. Two-thirds or more of the bicyclists used the cycle lane and the reserved waiting area. Signal violations by bicyclists were less than 20 percent. As many as 16 percent of motorists encroached into the BLs. At one intersection, more than half of all lead motorists encroached into the cyclists' reserved waiting area. The single-signal design is likely to be as effective as the two-signal design if a mandatory cycle lane and a distinctly-colored road surface in the cyclist areas are used. In Denmark, *recessed stop lines* (figure 13) for motor vehicles significantly reduced the number of crashes between right-turning motorists and cyclists going straight through the intersection (Herrstedt et al., 1994).

Organization of the Report

The results of this research are provided in three documents. This final report contains the comprehensive results pertaining to operations and conflicts. A research summary provides planners, engineers, and pedestrian/bicycle coordinators a tool with

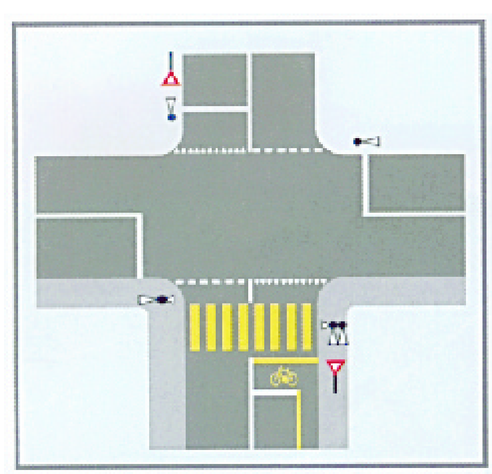
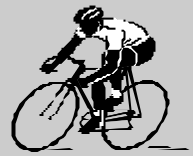


Figure 13. Bike box.

information about the operational and safety problems associated with BLs and WCLs, along with some suggested countermeasures for problem situations. A third document is a guidebook of current innovative bicycling practices. The guidebook is wide-ranging and covers topics such as on-street designs applicable to BLs or WCLs, retrofitting streets for bikes, use of colored pavement, bicycle traffic signals, and others.

In this final report, chapter 2 contains a description of the project research methodology and data collection techniques. Chapter 3 focuses on the comparative operational and safety differences between BLs and WCLs. Chapter 4 summarizes the main results and offers discussion about key issues.

Chapter
2
Methods



Overview

Bicyclists riding in either a BL or WCL were videotaped as they approached and proceeded through eight BL and eight WCL intersections with varying speed and traffic conditions in three cities. Approximately 4,600 bicyclists were videotaped in the three cities (2,700 riding in BLs and 1,900 in WCLs). The videotapes were coded to learn about operational characteristics (e.g., intersection approach position and subsequent maneuvers) and conflicts with motor vehicles, other bicycles, or pedestrians. A conflict was defined as an interaction between a bicycle and motor vehicle, pedestrian, or other bicycle such that at least one of the parties had to change speed or direction to avoid the other. Both bicyclist and motorist maneuvers in conflict situations were coded and analyzed. This would cover maneuvers such as a bicyclist moving incorrectly from the bicycle lane into the traffic lane prior to making a left turn, or conversely, a motor vehicle passing a bicyclist and then abruptly turning right across its path. Bicyclist experience data were also collected separately from the videotaping at each of the 16 data collection sites in each city through use of a short oral survey. Slightly more than 2,900 surveys were completed. These data were analyzed to learn about the age, riding habits, and experience levels of the bicyclists riding through these intersections.

City Selection

Considerable effort in the early part of the project was spent in identifying possible cities for study. Candidates were narrowed and visits made to Santa Barbara, CA; the Palo Alto area of CA; Madison, WI; Gainesville, FL; and Austin, TX. Based on key factors such as amount and type of facilities, number of riders, willingness and eagerness of local contacts to participate, and windows of opportunity (i.e., climate) for videotaping, Santa Barbara, CA, Gainesville, FL, and Austin, TX, were selected as primary project cities (figure 14). These were spread geographically across the United States and provided for a good comparative analysis. More detail about each follows.

Figure 14. Map of project cities.

Santa Barbara, California

This city has a population of about 90,000 with another 80,000 located in neighboring communities. This is an older city, and many of the streets have low motor vehicle speeds which, in turn, is good for bicycling. About 3 to 5 percent of commuting trips are estimated to be made by bicycling. The University of California at Santa Barbara is located about 11 km west of downtown (in Isla Vista) and may be reached by bicycle through an off-road facility. About 24 km of bicycle lanes are present and probably at least this amount of wide curb lanes, although no official measure exists. A large majority of the wide curb lanes were not planned as a specific bicycle facility; the curb lanes are simply wider in these locations due to repav-ing over the gutter pan, remarking of lanes after removal of parking, etc. The number of bicycle lanes started increasing after the adoption of the 1974 Bicycle Master Plan.

Gainesville, Florida

This city has a population of about 200,000 and is recognized as Florida's most bicycle-friendly community. The city is home to the University of Florida, and bicycle traffic is greatest in and around the campus. At present, Gainesville has about 130 km of roadways with bicycle lanes or paved shoulders and an additional 30 km of roadways with wide curb lanes. An established Bicycle/Pedestrian Program has been in place since 1983, and a full-time program coordinator has been employed for nearly all of that period. The bicycle program operations are centered in the traffic engineering department, which has done a very good job of tracking bicycle/motor vehicle crashes in the city.

Austin, Texas

Austin is the capital of Texas and has a population of almost 500,000. A bicycle plan

was developed in the late 1960s and many bike lanes were installed in the late 1970s and early 1980s. Approximately 85 km of bicycle lanes are now in place. No estimate is available for the number of wide curb lanes. A local policy states that street restriping will provide for wide curb lanes if possible. The basic city bicycle map is about 15 years old and is being replaced by a Geographic Information System version. The University of Texas is located in the central core and accounts for many riders, but there are also dedicated commuters. Between 1 and 2 percent of work trips are by bicycle. Recreational riders often use bicycle facilities to exit the city area for longer rides. The city bicycle program is located within the Public Works and Transportation Department, which provides access to other planners and transportation engineers.

Site Characteristics

The objective was to achieve a group of sites within each city that varied by width of BL or WCL (two levels), speed limit (two levels), and traffic volume (two levels). Such a matrix yields a total of eight sites. Thus, eight BL and eight WCL sites were selected for videotaping in each city. Selected breakpoint values were:

BL width - 1.5 m or less, >1.5 m
WCL width - 4.3 m or less, >4.3 m
Speed limit - 50 km/h or less, >50 km/h
Traffic volume - *Low* volume up to 7,500 vpd for 2 lanes; 15,000 vpd for 4 lanes, +etc.
High volume greater than 7,500 vpd for 2 lanes; 15,000 vpd for 4 lanes, etc.

We also tried to satisfy an objective of having 20 to 30 bicyclists per hour riding through the selected intersections. The following BL and WCL matrices show the overall mix for all three cities combined:

Bike Lane Sites

Width of BL	1.5 m or less		>1.5 m	
Traffic Volume	Low	High	Low	High
50 km/h or less	FL FL FL CA CA TX TX TX TX TX	FL FL CA	FL FL FL CA TX TX	CA CA
>50 km/h		CA TX		CA

Wide Curb Lane Sites

Width of WCL	4.3 m or less		>4.3 m	
Traffic Volume	Low	High	Low	High
50 km/h or less	FL TX	TX	FL FL TX TX TX	FL FL FL CA CA CA TX TX
>50 km/h		CA TX	CA	FL FL CA CA CA

As potential sites were selected in each city, we attempted to develop a mix based on the variable parameters shown above, as well as attempting to have variety in the sites that is representative of real-world conditions (e.g., BL and WCL sites with and without parking, BL sites with a weaving area and a bike pocket, BL sites with and without the stripe carried all the way to the intersection, BL and WCL sites where turning lanes were added at the intersection). In all three cities the preliminary site list of top candidates had to be altered, usually due to a small number of riders available for videotaping. BL sites were generally popular and tended to have a reasonably high number of bicyclists available. Sometimes the preliminary list of BL sites was altered because it was discovered that the viewing angle for videotaping was not good. It was difficult to find eight suitable WCL sites in any of the selected cities due to small numbers of bicyclists riding on WCL facilities.

In Gainesville and Austin, the selected sites were quite close to the university campuses, because this is where the majority of the bicyclists were located, and data could be collected in an efficient manner. In Santa Barbara, the university campus was remote, and student bicyclists were a much smaller part of the mix. In the project cites, BL sites tended to concentrate at low traffic speed and low traffic volume locations, while WCL sites tended to concentrate at high traffic volume locations. Overall, the matrices of final sites indicate a reasonable mix of variation.

Besides the items mentioned above, a variety of other descriptive data items were collected at each site. These included type of area, pavement marking (striping) information for the BLs and WCLs, traffic control device present, number of lanes, estimated driving speed, presence of parking, average annual daily traffic (AADT), and others.

Videotaping of Bicyclists

The initial plan was to videotape bicyclists both at midblock and intersection locations. However, it became apparent that sample sizes would be relatively small if the videotaping task was divided in this fashion. Thus, the decision was made to forego the midblock videotaping and instead videotape each intersection twice for the following reasons:

- Intersections account for about half of all bicycle-motor vehicle crashes.
- Because of the need to make turning movements, intersections were expected to lead to more conflicts between vehicles, pedestrians, and other bicycles.
- It was of interest to learn about the maneuvers bicyclists make to travel through intersections, such as the ways left turns are made.
- The camera position would allow viewing of the approaching bicyclists from a considerable distance back from the intersection (not unlike a midblock situation).

Intersections and the approaches to intersections (referred to as midblock hereafter) were thus the focus of the data collection effort. Bicyclists were videotaped in the oncoming direction as they approached the selected intersections. The two-person data collection team usually mounted the camera on a 3-m stepladder set up some 30 to 40 m on the far side of the intersection. The location was such that the oncoming bicyclists generally were not aware of the camera until close to the intersection. The stepladder was quite beneficial in providing a viewing angle above traffic. In a few of the Gainesville intersections, a platform truck belonging to the city was used to enable a better viewing position than could be afforded by a stepladder.

Normally the camera position allowed for a view of more than 150 m back from the intersection. Five 46-cm traffic cones were set up at 30-m intervals from the intersection stop bar location (at 30, 60, 90, 120, and 150 m). Approaching bicyclists were usually captured before reaching the 150-m cone and followed through the intersection (figure 15). The data collector would zoom in on the bicyclist to enable a better view of any kinds of bicycle-motor vehicle interactions. If the bicyclist had to stop for a traffic signal, the data collector would ascertain if it were possible to videotape another approaching bicyclist. If so, this bicyclist would be followed up to the intersection, and then both bicyclists would be taped as they rode through. Each intersection was videotaped twice for 2 hours at each session. The basic plan was to videotape selected intersections during both weekday and weekend times if riders were present during these periods. However, if

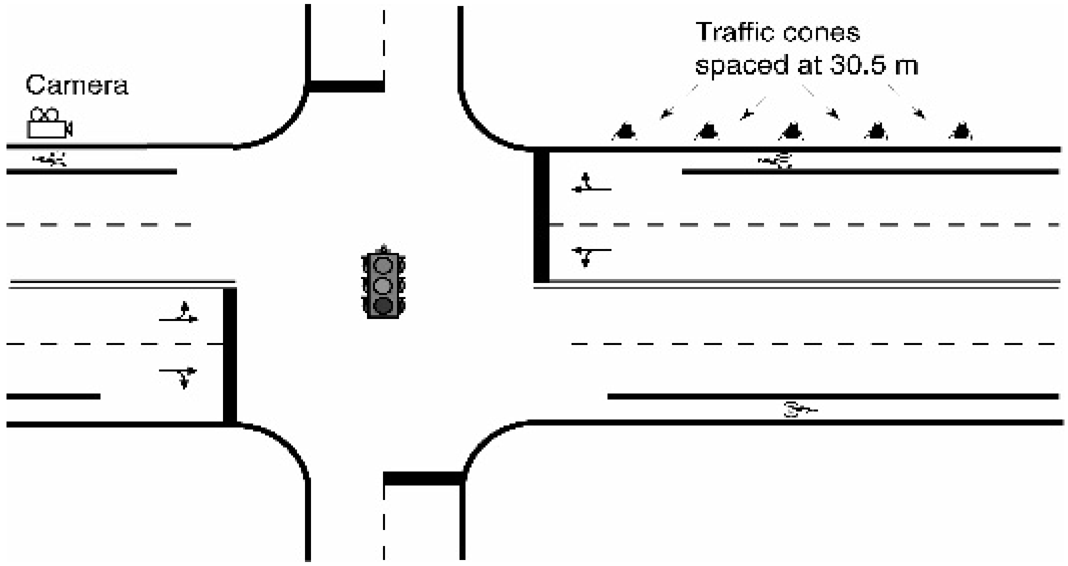


Figure 15. **Typical data collection setup.**

riders tended to travel through an intersection mainly on weekends (say, as part of a heavily traveled recreation route), then videotaping would be done twice on weekends. On the other hand, if commuters were the norm and little riding was done on weekends, then videotaping would be done twice during weekdays. Generally, all 16 sites were videotaped once before the second round of taping began. As stated earlier, approximately 4,600 bicyclists were videotaped in the three cities (2,700 at BL sites and 1,900 at WCL sites).

Besides the bicyclist videotaping described above, 15-minute samples of traffic were also videotaped that corresponded to the time of the bicycle videotaping. The camera was positioned at a location where all the legs of the intersection could be observed. This videotape enabled counts of motor vehicles traveling through the intersection and thus some measure of exposure to traffic.

Bicyclist Experience Data

A one-minute oral survey was used to collect information about the bicyclists riding through the intersections. Data collectors positioned themselves such that bicyclists could be safely stopped before reaching the intersection proper. The first data collector would stand about 50 m in front of the second data collector and ask approaching bicyclists to stop for a 1-minute bicycle survey ahead. Four questions were asked:

- What is your age?
- On average, how many days a week do you ride your bike?
- On average, about how many miles do you ride each week?
- How would you classify yourself with respect to the experience you have riding on city streets? (1 or 2, shown below)

1. I feel comfortable riding under most traffic conditions, including major streets with busy traffic and higher speeds.

OR

2. I only feel comfortable riding on streets with less traffic and lower speeds, on streets with bicycle lanes, or on sidewalks.

In addition, information was coded pertaining to where the bicyclists were riding (road, sidewalk, or other location) as they approached the survey station, and the race, gender, and helmet use of the bicyclist. (The experience data collection form is shown in appendix A.) The data enabled us to gain information about the experience level of bicyclists riding through the particular intersection. Such knowledge could be directly relevant to the types of maneuvers and conflicts seen at the site. These data were entered directly to a spreadsheet for analysis.

Each experience data collection session lasted 2 hours and was matched to the videotaping (i.e., same basic time of day and day of week), and almost all were done a few days after the videotaping. Thus, if videotaping was done on both a weekday and a weekend, then experience data would be collected on a weekday and weekend. If filming was done only on weekdays or only on weekends, then experience data would be limited to this time period as well. Using this method, slightly more than 2,900 surveys were completed. Generally, about two-thirds of the bicyclists passing any given site consented to an interview. The most likely reason for not stopping was being in a hurry to get to class, a meeting, etc. Sometimes the bicyclists unable to stop came back later and completed a survey. Characteristics of the riders *not* completing a survey were not obtained, but there was no evidence that this group was different from the group completing the survey.

Coding of Videotape Data

A form for coding a variety of items associated with a bicyclist riding through an intersection was developed, tested, and revised several times before the form was satisfactory. The objective was to code actions associated both with a "midblock" (the intersection approach) and an intersec- tion area. Midblock was thus defined as the area between the third and fifth traffic cones set up on the approach leg (90 to 150 m from the intersection stop bar location). The intersection was defined as the area covered by the first three traffic cones (0 to 90 m back from the stop bar location).

The following are examples of the types of variables that were coded:

- Bicyclist riding wrong way.
- Bicyclist demographics and helmet use.
- Midblock positions and movements.
- Bicyclist spacing from the curb or gutter pan seam and from a passing motor vehicle.
- Bicyclist midblock behaviors (e.g., turning across a lane of traffic).
- Midblock conflict information.
- Intersection positions and movements.
- Bicyclist straight, left turn, and right turn methods.
- Bicyclist straight, left turn, and right turn conflict information.

The complete working form may be found in appendix B.

During initial coding practice, questions were discussed and resolved. Data coders were constantly exchanging information at this stage so as to develop consistency. Once the coding process was finalized, a computerized entry screen was created, pilot tested, and "debugged." From this point onward, all videotape data were coded via the computer screen and automatically stored in a database.

Creation of Project Database

Once videotape coding had been completed, a database of various files was assembled. This included:

- The coded videotape items.
- The experience file.

- The motor vehicle traffic count file based on the 15-minute samples.
- The file describing the intersection features.

Coding and Analysis of Crash Data

Two years of recent (1994 and 1995) bicycle-motor vehicle crash data were obtained from each of the three cities. Crashes from one complete year (1995) from each city were "typed" following the methodology originally developed by the National Highway Traffic Safety Administration (NHTSA) in the late 1970s[1] and being modified in partnership with the FHWA for computer application. The computer software will be known as PBCAT (Pedestrian and Bicycle Crash Analysis Tool), a user-friendly software package developed for FHWA by the University of North Carolina Highway Safety Research Center.

Crashes from each city were relatively sparse, and very few matched the intersections selected for videotaping. However, city trends were examined to determine if overall crash patterns were similar to the types of behaviors and conflicts coded from the videotape data.

The chapter that follows discusses cyclist characteristics and operational and safety findings associated with BLs and WCLs.

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[1]For more specific background on crash typing, see Hunter, Stutts, Pein, and Cox (1996).

Chapter

3

Results

Using the methods described in the previous chapter, this chapter presents results of the analysis of the data. The sections that follow are descriptive and focus on cyclist characteristics and midblock (or intersection approach) and intersection operational and safety findings associated with BLs and WCLs. Tables are sometimes grouped for ease in presentation. Findings from statistical models are then presented. The chapter concludes with a clinical analysis of high-rate conflict sites and the serious conflicts, and an examination of the bicycle-motor vehicle crash data from the project cities.

Bicyclist Characteristics

Videotape data

Several variables describing the 4,589 videotaped bicyclists are summarized in table 1. This table is typical of others that follow. The variables are cross-tabulated by whether at BL or WCL sites. Frequencies and column percentages are routinely presented. Totals differing from 4,589 are due to missing values. The text occasionally includes some information that was not placed in a table.

Statistical testing of relationships was done using chi-square tests to determine if differences between BL and WCL distributions were significant or due to chance alone. When the distributions are significantly different, asterisks (**) are placed beside the name of the variable (e.g., “Gender” in table 1), and the level of significance, or p-value, is shown with the appropriate number of asterisks at the bottom of the table. Using “Gender” from table 1 as an example, a p-value of < .05 (single *) means that the difference in the distributions could be due to chance less than 5 times out of 100.

Generally, the tables show all levels of a variable to convey more information to the reader; however, categories were grouped when necessary to permit appropriate statistical testing. In the text that follows, a single triangle is used to indicate a major individual cell chi-square contribution to a significant chi-square value for the overall distribution. Chi-square testing was not performed in cases where the distributions produced zero cells due to all effects of a variable being directly related to either a BL or WCL (e.g., turning left from a BL could not be done from a WCL).

Table 1 shows that slightly more than three-fourths of the bicyclists observed on the videotapes were male. The proportion of males was slightly larger on BLs (77 percent) than WCLs (74 percent), while there were slightly more females riding on WCLs (23 percent) than BLs (20 percent).

Age of bicyclists was estimated from observing the videotapes and categorized into the following groups: less than 16, 16-24, 25-64, and greater than 64 years. Overall, almost 55 percent of the bicyclists were age 16-24, and another 44 percent age 25-64. This result was not surprising, given that we were trying to capture cyclists riding in traffic, as well as the fact that cyclists going to and from college campuses were prevalent, particularly in Gainesville and Austin. Some 58 percent of the bicyclists riding on WCLs were judged to be age 16-24, compared with 53 percent for those riding on BLsþ. More than 46 percent of the cyclists riding on BLs were age 25-64þ, as opposed to 40 percent for those on WCLs.

Observed helmet use was 32 percent and varied only slightly by facility type. Overall, 5.6 percent of the bicyclists were riding the wrong way (i.e., facing traffic), 1.3 percent of these in the road and 4.3 percent on the

Table 1. Videotaped bicyclist characteristics.

Gender*	BLs	WCLs	Total
Male	2055 (77.3)	1434 (74.2)	3489 (76.0)
Female	538 (20.3)	442 (22.9)	980 (21.4)
Unsure	64 (2.4)	56 (2.9)	120 (2.6)
Total	2657 (57.9)	1932 (42.1)	4589 (100.0)

* p < .05

Helmet Use	BLs	WCLs	Total
Yes	822 (31.0)	622 (32.5)	1444 (31.6)
No	1827 (69.0)	1295 (67.6)	3122 (68.4)
Total	2649 (58.0)	1917 (42.0)	4566 (100.0)

Age* **	BLs	WCLs	Total
< 16	23 (0.9)	27 (1.5)	50 (1.1)
16-24	1350 (52.6)	1077 (58.1)	2427 (54.9)
25-64	1183 (46.1)	746 (40.2)	1929 (43.6)
65+	10 (0.4)	5 (0.3)	15 (0.3)
Total	2566 (58.0)	1855 (42.0)	4421 (100.0)

*** p < .001

Wrong Way Riding* **	BLs	WCLs	Total
Yes, in road	26 (1.0)	32 (1.7)	58 (1.3)
Yes, sidewalk	61 (2.3)	136 (7.0)	197 (4.3)
No	2566 (96.7)	1763 (91.3)	4329 (94.4)
Total	2653 (57.9)	1931 (42.1)	4584 (100.0)

*** p < .001

Level of Significance
* p < .05
** p < .01
*** p < .001

sidewalk.[1] Wrong-way riding was prevalent on sidewalks (7 percent at WCL sites versus 2.3 percent at BL sites). These results were re-examined by eliminating the sidewalk riding and comparing the wrong-way riding in the road (1.7 percent for WCL sites and 1.0 percent for BL sites) versus correctly riding with traffic. Wrong-way riding was found to be significantly associated with WCL sitesþ.

[1]While wrong-way riding on a sidewalk is not necessarily illegal or improper behavior, it can lead to operational and safety problems with motor vehicle traffic. Thus, it has been defined and used in this report as a behavioral characteristic of bicyclists.

Bicyclist experience survey results

In addition to the videotape data, bicyclist experience data were gathered from a separate survey administered to bicyclists passing through each of the data collection sites. Information was gathered on the gender, age, race, and helmet use of the bicyclist; average number of days a week ridden; average number of miles a week ridden; location where riding at the time of the survey (roadway, sidewalk or other); and the rider's opinion of his or her level of riding experience (either experienced or casual). (See appendix A) Information was gathered from 2,907 bicyclists, 1,653 (57 percent) at BL locations and 1,254 (43 percent) at WCL locations. Data were collected during both weekday and weekend time periods, although the overwhelming majority (97 percent) of surveys were completed by bicyclists riding on a weekday.

Table 2 provides the demographics of the riders completing the surveys.

Table 2. Experience survey bicyclist characteristics.

Gender	BLs	WCLs	Total
Male	1225 (74.4)	922 (73.6)	2147 (74.1)
Female	421 (25.6)	331 (26.4)	752 (25.9)
Total	1646 (56.8)	1253 (43.2)	2899 (100.0)

Helmet Use	BLs	WCLs	Total
Yes	604 (36.7)	484 (38.6)	1088 (37.5)
No	1044 (63.4)	769 (61.4)	1813 (62.5)
Total	1648 (56.8)	1253 (43.2)	2901 (100.0)

Age	BLs	WCLs	Total
< 16	22 (1.3)	15 (1.2)	37 (1.3)
16-24	641 (38.9)	516 (41.2)	1157 (40.0)
25-64	982 (59.6)	717 (57.2)	1699 (58.5)
65+	4 (0.2)	5 (0.4)	9 (0.3)
Total	1649 (56.8)	1253 (43.2)	2902 (100.0)

Race* **	BLs	WCLs	Total
White	1316 (79.9)	1061 (84.7)	2377 (82.0)
Black	31 (1.9)	39 (3.1)	70 (2.4)
Hispanic	174 (10.6)	88 (7.0)	262 (9.0)
Asian	103 (6.3)	52 (4.2)	155 (5.3)
Other	23 (1.4)	12 (1.0)	35 (1.2)
Total	1647 (56.8)	1252 (43.2)	2899 (100.0)

*** p < .001

Level of Significance
* p < .05
** p < .01
*** p < .001

Nearly three-fourths (74 percent) of the bicyclists were male, slightly lower than the 76-78 percent male riders (adjusting for unknowns) captured on videotape. Bicyclists participating in the survey were also less likely to be in the 16-24 year age category and more likely to be aged 25-64: 40 percent of the surveyed bicyclists were age 16-24, compared with 55 percent of the videotaped bicyclists, and 59 percent were age 25-64, versus 44 percent for the videotape. These differences may reflect actual differences in the videotape and survey samples or a greater willingness on the part of the older cyclists to participate in the survey. However, they most likely reflect a tendency on the part of the data coders to underestimate the ages of the bicyclists viewed on videotape.

Helmet use was also higher for the exposure data sample than for the videotape riders — 38 percent versus 32 percent. Information on bicyclist race was collected for the exposure sample only, based on the judgment of the data collector, and showed higher percentages of whites and blacks riding in WCL locations,þ and more Hispanics and Asians riding in BL locations.þ This was the only rider characteristic variable to show significant differences by facility type.

Information on self-reported riding experience is provided in table 3. Eighty percent of the bicyclists surveyed reported riding five or more days per week. Those surveyed at WCL locations were especially likely to ride five days a week, and less likely to ride only one to three days a week. Just over 40 percent reported riding 10-25 miles per week, and another 25 percent 26-50 miles a week. Less than 7 percent rode more than 100 miles a week, and for the total distributions there were no differences with respect to facility type. Finally, 34 percent of the bicyclists considered themselves to be experienced, versus merely casual, riders. This percentage also did not vary by WCL versus BL facility. Bicyclists surveyed at WCL sites, however, were more frequently observed riding on sidewalks as they approached the survey station: nearly one out of five bicyclists surveyed at WCL sites was observed riding on the sidewalk, compared with only 6 percent of those surveyed at BL sites.

Since the bicyclists in the exposure sample were shown to be older than those in the videotape sample, rider age (<25, was cross-tabulated by the various riding experience variables. Generally, the younger riders (<25) were more likely to ride five days a week (p<.001), more likely to ride 25 or fewer miles per week (p<.001), and more likely to be observed riding on a sidewalk (p<.001). They were also much *less* likely to be observed wearing a helmet (p<.001). There were no significant differences in the number of younger and older bicyclists who viewed themselves as experienced riders. These findings suggest that the videotaped riders, while no more "experienced" than the exposure riders, may ride fewer miles per week and may be more likely to peak at riding five days a week. They may also have a lower overall helmet wearing rate. However, without more specific information on the nature and extent of any misclassification of rider age, no adjustments were made to the exposure data, and the data were incorporated into the statistical modeling (described later in this chapter) as site-dependent variables.

Table 3. Experience survey riding characteristics.

Days Ride Per Week***	BLs	WCLs	Total
1	37 (2.3)	8 (0.6)	45 (1.6)
2	68 (4.1)	23 (1.8)	91 (3.1)
3	142 (8.6)	81 (6.5)	223 (7.7)
4	112 (6.8)	88 (7.1)	200 (6.9)
5	612 (37.3)	560 (44.9)	1172 (40.6)
6	141 (8.6)	96 (7.7)	237 (8.2)
7	530 (32.3)	392 (31.4)	922 (31.9)
Total	1642 (56.8)	1248 (43.2)	2890 (100.0)

*** p < .001

Miles Ride Per Week	BLs	WCLs	Total
< 10	205 (12.5)	126 (10.1)	331 (11.5)
10-25	662 (40.3)	506 (40.7)	1168 (40.5)
26-50	408 (24.9)	325 (26.2)	733 (25.4)
51-75	156 (9.5)	118 (9.5)	275 (9.5)
76-100	98 (6.0)	87 (7.0)	185 (6.4)
101-150	57 (3.5)	42 (3.4)	99 (3.4)
151+	55 (3.4)	38 (3.1)	93 (3.2)
Total	1641 (56.9)	1242 (43.1)	2883 (100.0)

Where Riding When Surveyed***	BLs	WCLs	Total
Road	1556 (94.4)	1001 (80.0)	2557 (88.2)
Sidewalk	93 (5.6)	235 (18.8)	328 (11.3)
Other	0 (0.0)	15 (1.2)	15 (0.5)
Total	1649 (56.9)	1251 (43.1)	2900 (100.0)

*** p < .001

Type Rider	BLs	WCLs	Total
Experienced	560 (34.5)	425 (34.0)	985 (34.3)
Casual	1064 (65.5)	824 (66.0)	1888 (65.7)

Level of Significance
* p < .05
** p < .01
*** p < .001

Midblock Actions

Movements

Midblock (or the intersection approach) was defined as between 90 and 150 m from the intersection (see figure 15). Within this midblock zone, about 50 percent of the bicyclists approaching the intersections were in BLs, another 27 percent in WCLs, 7 percent on the sidewalk, and 9 percent in a traffic lane (generally the lane adjacent to a BL or WCL). Whatever their initial midblock position, 83 percent of the bicyclists did not change this position throughout the midblock zone. Other variables describing midblock movements are presented in table 4.

Table 4. Midblock actions.

Bicyclist Midblock Movement***	BLs	WCLs	Total
Straight to intersection	2409 (95.4)	1597 (93.1)	4006 (94.5)
Crossed to left before intersection	82 (3.3)	48 (2.8)	130 (3.1)
Turned right before intersection	31 (1.2)	63 (3.7)	94 (2.2)
Other movement	4 (0.2)	7 (0.4)	11 (0.3)
Total	2526 (59.6)	1715 (40.4)	4241 (100.0)

*** p < .001

Motor Vehicle Encroached into Adjacent Traffic Lane***	BLs	WCLs	Total
Yes	22 (6.8)	28 (16.7)	50 (10.1)
No	289 (88.9)	131 (78.0)	420 (85.2)
Unsure	14 (4.3)	9 (5.4)	23 (4.7)
Total	325 (65.9)	168 (34.1)	493 (100.0)

*** p < .001

Bicyclist Riding Next to Parked Vehicle***	BLs	WCLs	Total
Yes	615 (23.2)	236 (12.3)	851 (18.6)
No	2039 (76.8)	1690 (87.8)	3729 (81.4)
Total	2654 (58.0)	1926 (42.1)	4580 (100.0)

*** p < .001

Encroachment Led to Conflict	BLs	WCLs	Total
Yes	1 (4.2)	1 (3.3)	2 (3.7)
No	23 (95.8)	29 (96.7)	52 (96.3)
Total	24 (44.4)	30 (55.6)	54 (100.0)

Level of Significance
* p < .05
** p < .01
*** p < .001

Ninety-five percent rode straight to the intersection. About 3 percent crossed the street to the left in advance of the intersection (proportion- ally more from BLs than WCLs), and another 2 percent turned right prior to the intersection (proportionally more from WCLsþ than BLs).[2]

[2]It is important to note that these movements prior to the intersection may be more a function of the destination preference of bicyclists than a statistically significant finding associated with either a BL or WCL. For example, if bicyclists desire to make an advance crossover to the left prior to an intersection because of the difficulty of making a left turn at the intersection proper, the advance crossover would likely be made whether a BL or WCL was present.

Proportionally twice as many bicyclists were riding next to parked vehicles in BLsþ (23 percent) than in WCLs (12 percent), but there were a greater number of BL sites that contained parking as part of the BL. Without proper enforcement, it would appear that motor vehicles are not hesitant to park (legally or illegally) in either kind of facility.

Overall 10 percent of motor vehicles passing bicycles on the left encroached into the adjacent motor vehicle traffic lane; 17 percent of the motor vehicles traveling in a WCL encroached while 7 percent of the vehicles traveling on facilities with a BL encroached. This tendency agrees with results from a recent study for the Florida DOT (Harkey and Stewart, 1997). Of the definite encroachments into the adjacent traffic lane, only two (one each from a BL and WCL) resulted in a conflict with another motor vehicle.

Midblock spacing between bicycles and motor vehicles

Whenever possible, measurements were made of distances between the bicycle and the curb face or edge of road (or gutter pan seam, if present), and between the bicycle and a passing motor vehicle. Two separate files were developed, one that contained only the first type of measurement, bike to curb or gutter pan seam ("curb space") made from observations where the bike was not being passed. The second file contained both types of measurements, "curb space" and "car space," made from observations where the bike *was* being passed by a motor vehicle.

Statistical models were developed to investigate how these spacing variables differed, on average, as a function of the various roadway and traffic characteristics. Least squares regression analysis was used in developing these models. Thus, it was assumed that the observed distances followed a normal distribution with mean value, μ, of the form,

$$\mu = þ_o + þ_1 X_1 + \dots + þ_k X_k$$

, where the variables $X_1, X_2, \dots, X_k$ represent characteristics of the roadway, bicyclist, and traffic conditions, and the þ's are coefficients estimated by fitting the model to data. Consider first a model for average curb space for bicycles that were *not* being passed and where the bicycle was *not* being ridden beside a parked vehicle. As usual, this model was developed by trying various combinations of explanatory variables potentially associated with the response variable and retaining those for which the association was statistically significant. Results from carrying out this process are presented in table 5. A total of 1,393 observations were used in this model.

The model shows that both a variable indicating the presence of a BL and the width of the BL were statistically significant, while WCL width was not significant when included in the model. Thus, average curb space for a WCL is given simply by the constant plus the traffic volume effect. For BLs with widths $\leq$ 1.6 m, the average bicycle distance from the curb was less than that for WCLs having the same traffic volume. For BLs greater than 1.6 m wide, however, the average bicycle distance from the curb was greater than for WCLs with similar traffic volumes. For example, using traffic volume of 400 vehicles per hour, the model gives the value of 0.9 m for the average distance from bike to curb at WCL sites. The corresponding average distances on BLs of 1.2 m, 1.8 m, and 2.1 m are 0.7 m, 1.0 m, and 1.2 m, respectively.

Table 5. Model for distance from curb for bikes not being passed.

Variable	estimate (þ)	P-value
Constant	3.21	.0001
Traffic volume (vph)	-.001	.0001
BL indicator	-2.71	.0001
BL width (m)	1.74	.0001

It should be kept in mind that the estimated models are very much dependent on the nature of the data from which they are developed. In particular, the BLs tended to be quite wide, ranging from 1.2 to 2.9 m, with an average of 1.8 m. Total width (BL + adjacent traffic lane) averaged 5.6 m for BL sites versus 4.7 m for WCL sites. This variability in widths across facility types makes it difficult to compare the model results for Bls and WCLs.

On-street parking was part of the bicycle facility at some sites (e.g., a shared parking and BL). At these sites, some bikes were observed riding next to *parked vehicles*. In these cases, spacing distance was measured from the bike to the parked vehicle rather than to the curb. There were 270 such observations of bicycles not being passed by a motor vehicle. These observations were added to the data set and a model was fitted to both these bike-to-curb and bike-to-parked vehicle distances, which con- tained, in addition to the variables of table 5, a variable indicating that the bike was riding beside a parked vehicle. This variable was statistically significant, with an estimated coefficient of -.347. This would seem to indicate that bicyclists ride closer to parked vehicles than they do to the curb when parked vehicles are not present. However, average BL widths were greater by the amount 0.2 m when parking was part of the facility, and the estimated BL width effect in this model was 1.76. So the increased width contri- buted an amount (1.76) (0.2) = .353 to the estimated distance between bike and or parked vehicle. Thus, the estimated parked vehicle effect was simply off- setting the increased BL width at these sites and should not be interpreted as having any general applicability. In other words, on average, bicyclists rode about the same distance from parked vehicles at BL sites with parking as they did to the curb (or gutter pan seam) when parked vehicles were not present.

A model for average curb space based on 319 measurements made on bikes *being passed by motor vehicles* is presented in table 6. For this model and the one presented earlier in table 5, both the variables included in the models and the estimates are quite similar. The major difference is in the constant term, which shows the bikes to be positioned about 0.3 m closer, on average, to the curb when being passed than when not. This model again predicts distances from bike to curb to be smaller for narrow Bls (width < 1.5 m) and larger for wider BLs (width ≥ 1.5 m) than for WCLs with similar traffic volumes.

Table 6. Model for distance from curb for bikes being passed.

Variable	estimate (þ)	P-value
Constant	2.25	.0001
Traffic volume (vph)	-.0004	.0001
BL indicator	-2.28	.0001
BL width (m)	1.57	.0001

Table 7. Model for distance between bikes and passing motor vehicles.

Variable	estimate (þ)	P-value
Constant	.37	.6164
Traffic volume (vph)	-.001	.0004
Total width (m)	1.08	.0001
Speed (km/h)	.04	.000

Results from a model for distance between bike and *passing vehicle* are presented in table 7. This model was based on 318 observations. Note that this model does not contain either the BL indicator variable or BL width as a separate variable. These variables were tried and found to be non-significant, indicating that type of facility (BL versus WCL) does not affect the separation distance. Instead it contains a total width variable, which consists of BL width plus the width of the adjacent traffic lane or the width of the WCL when no BL is present. Thus, this width effect applies to the total space available to the bicycle and motor vehicle, whether the space is a WCL or a BL plus an adjacent traffic lane. Estimated driving speed is also a factor in this model, with spacing between vehicles and bikes tending to increase as speed increases.

Behaviors

Various behaviors of bicyclists in the midblock area were coded from the videotape. A complete list of possible behaviors may be found as part of the coding form in appendix B. The behaviors were divided into three sections: (1) bicycle-motor vehicle common actions, (2) motor vehicle initiated events, and (3) bicycle initiated events.[3] Common actions were behaviors that either a bicycle or motor vehicle could perform, such as failing to stop for a stop sign or traffic signal, improper turns, improper lane use, etc. Examples of motor vehicle initiated events included long-term travel in the BL or right edge of the WCL, turning right soon after overtaking a bicyclist, and entering/ exiting on-street parking. Examples of bicycle initiated events included turning or swerving across a lane of traffic, riding in between slowed/stopped traffic, and stunt riding or other erratic riding. Also included in this last category were encounters with pedestrians or other bicyclists (e.g., a bicyclist avoiding another bicyclist traveling in the opposing direction in BL, or a bicyclist avoiding a jogger in a BL).

[3]The motor vehicle portions of the three items discussed above were only coded for conflicts between bicycles and motor vehicles. Conflicts are discussed later in the chapter.

Table 8 shows a list of behaviors distributed by type of site (BL or WCL). Some grouping of behaviors has been performed to allow valid statistical comparisons. Behaviors seen proportionally more often in BLs included:

- The bicyclist not stopping at a stop sign (there was an intersecting street in the midblock area at a few sites).
- The bicyclist having to slow/stop/swerve due to traffic *not* influenced by the intersection ahead (e.g., a bicyclist slows when a motor vehicle pulls into the BL from a driveway)þ.
- The bicyclist turning or swerving across a lane of trafficþ.

Table 8. Midblock behaviors.

Behavior* **	BLs	WCLs	Total
None	2085 (84.8)	1458 (89.9)	3543 (86.8)
Bike did not stop for stop sign	13 (0.5)	1 (0.1)	14 (0.3)
Bike slowed/stopped/ swerved for traffic not at intersection	55 (2.2)	17 (1.1)	72 (1.8)
Bike entered roadway from sidewalk or over curb	9 (0.4)	10 (0.6)	19 (0.5)
Bike turned or swerved across a lane of traffic	111 (4.5)	49 (3.0)	160 (3.9)
Bike stunt riding	12 (0.5)	7 (0.4)	19 (0.5)
Bikes riding two abreast	23 (0.9)	17 (1.1)	40 (1.0)
Bike encounter with pedestrian	21 (0.9)	15 (0.9)	36 (0.9)
Bike encounter with another bike	16 (0.7)	2 (0.1)	18 (0.4)
Other behaviors	113 (4.6)	46 (2.8)	159 (3.9)
Total	2458 (60.3)	1622 (39.8)	4080 (100.0)

*** p < .001

Vehicle in Vicinity for Midblock Behaviors* **	BLs	WCLs	Total
Yes	1790 (72.1)	1371 (77.8)	3161 (74.5)
No	679 (27.4)	389 (22.1)	1068 (25.2)
Unsure	14 (0.6)	3 (0.2)	17 (0.4)
Total	2483 (58.5)	1763 (41.5)	4246 (100.0)

*** p < .001

Level of Significance
* p < .05
** p < .01
*** p < .001

Table 8. Midblock behaviors (con't).

Midblock Behaviors with a Motor Vehicle in the Vicinity* **	BLs	WCLs	Total
None	1412 (84.1)	1088 (90.1)	2500 (86.6)
Bike did not stop for stop sign	5 (0.3)	1 (0.1)	6 (0.2)
Bike slowed/stopped/ swerved for traffic not at intersection	48 (2.9)	17 (1.4)	65 (2.3)
Bike entered roadway from sidewalk or over curb	8 (0.5)	7 (0.6)	15 (0.5)
Bike turned or swerved across a lane of traffic	76 (4.5)	34 (2.8)	110 (3.8)
Bike stunt riding	9 (0.5)	5 (0.4)	14 (0.5)
Bikes riding two abreast	20 (1.2)	11 (0.9)	31 (1.1)
Bike encounter with pedestrian	12 (0.7)	10 (0.8)	22 (0.8)
Bike encounter with another bike	8 (0.5)	1 (0.1)	9 (0.3)
Other behaviors	82 (4.9)	34 (2.8)	116 (4.0)
Total	1680 (58.2)	1208 (41.8)	2888 (100.0)

*** $p < .001$

Level of Significance
* $p < .05$
** $p < .01$
*** $p < .001$

- Bicyclist encounters with other bicyclistsþ.

- "Other" kinds of behaviorsþ.

Examples of the "other" kinds of behaviors (low frequencies of each) included improper turns and lane changes, motor vehicles parked in BLs, weaving while riding in the BL, weaving in between motor vehicles, and carrying a bag in hand.

Behaviors seen proportionally more often in WCLs included:

- The bicyclist entering the roadway from the sidewalk or over the curb (only slightly higher than for BL).

- Bicyclists riding two abreast.

When any of the midblock behaviors were observed, a code was used to denote whether there was a motor vehicle in the vicinity, obviously implying that the behaviors were potentially more dangerous if this was the case. "In the vicinity" was defined as approximately 66 m. Overall, vehicles were in the vicinity nearly three-fourths of the time a bicyclist was observed performing the behavior (72 percent for BL sites versus 78 percent for WCL sites).

The next part of table 8, "Midblock Behaviors with a Motor Vehicle in the Vicinity," amplifies the information above by allowing specific comparisons for the behaviors. For example, of the 160 bicyclists who turned or swerved across a lane of traffic, 110 did so with a motor vehicle in the vicinity.

Intersection Actions

Movements

For bicyclists proceeding toward the camera, the beginning of the intersection was defined as starting 90 m upstream of the stop bar, and included the intersection proper (see figure 15). Table 9 shows that 49 percent of the bicyclists were riding in a BL and 31 percent in a WCL as they approached the intersection. (No statistical test of the overall distribution was performed due to the separation of bicyclists into the initial approach of either a BL or WCL.) Almost 8 percent were on the sidewalk and 6 percent in a motor vehicle traffic lane (i.e., in *neither* a BL or WCL).

Table 9. Intersection actions.

Bicyclist Initial Intersection Approach Position	BLs	WCLs	Total
Bike lane	2028 (81.1)	0 (0.0)	2028 (48.5)
Wide lane	0 (0.0)	1278 (76.0)	1278 (30.6)
Sidewalk	82 (3.3)	245 (14.6)	327 (7.8)
Traffic lane	216 (8.6)	53 (3.2)	269 (6.4)
Left turn lane	5 (0.2)	2 (0.1)	7 (0.2)
Right turn lane	29 (1.2)	5 (0.3)	34 (0.8)
Other	61 (2.4)	36 (2.1)	97 (2.3)
Not through intersection	79 (3.2)	63 (3.8)	142 (3.4)
Total	2500 (59.8)	1682 (40.2)	4182 (100.0)

Bicyclist Obeyed Traffic Signal	BLs	WCLs	Total
Obeyed signal	1401 (91.2)	1136 (92.0)	2537 (91.6)
Disobeyed signal	135 (8.8)	99 (8.0)	234 (8.4)
Total	1536 (55.4)	1235 (44.6)	2771 (100.0)

Bicyclist Obeyed Stop Sign***	BLs	WCLs	Total
Obeyed sign	554 (80.6)	116 (55.2)	670 (74.7)
Disobeyed sign	133 (19.4)	94 (44.8)	227 (25.3)
Total	687 (76.6)	210 (23.4)	897 (100.0)

*** p < .001

Bicyclist Changed Intersection Approach Position To	BLs	WCLs	Total
Bike lane	87 (3.6)	0 (0.0)	87 (2.2)
Wide lane	0 (0.0)	34 (2.1)	34 (0.8)
Sidewalk, path	66 (2.7)	41 (2.5)	107 (2.7)
Traffic lane	404 (16.8)	258 (16.0)	662 (16.5)
Left turn lane	109 (4.5)	27 (1.7)	136 (3.4)
Right turn lane	173 (7.2)	103 (6.4)	276 (6.9)
Other	30 (1.3)	30 (1.9)	60 (1.5)
No change	1540 (63.9)	1122 (69.5)	2662 (66.2)
Total	2409 (59.9)	1615 (40.1)	4024 (100.0)

Result of Disobeying Signal	BLs	WCLs	Total
Maneuver safe	109 (84.5)	75 (78.1)	184 (81.8)
Maneuver somewhat unsafe	17 (13.2)	19 (19.8)	36 (16.0)
Maneuver definitely unsafe	3 (2.3)	2 (2.1)	5 (2.2)
Total	129 (57.3)	96 (42.7)	225 (100.0)

Result of Dis-obeying Sign***	BLs	WCLs	Total
Maneuver safe	100 (78.1)	87 (94.6)	187 (85.0)
Maneuver somewhat unsafe	24 (18.8)	5 (5.4)	29 (13.2)
Maneuver definitely unsafe	4 (3.1)	0 (0.0)	4 (1.8)
Total	128 (58.2)	92 (41.8)	220 (100.0)

*** p < .001

Level of Significance
* p < .05
** p < .01
*** p < .001

A large number of bicyclists in the "other" category came into the intersection area from a driveway or other intersecting street. Proportionally more bicyclists approached the intersection on a sidewalk when the facility was a WCL (15 percent) compared with a BL (3 percent). On the other hand, proportionally more bicyclists approached the intersection in a motor vehicle traffic lane when a BL was present (9 percent) compared with a WCL (3 percent).

Overall, two-thirds of the bicyclists did not change their position as they traveled through the 90-m intersection area (similar to above, no statistical test performed). There were proportionally more bicyclists who changed to left turn lanes from BLs. Most of the "other" movements involved bicyclists turning off to either the left or right before the intersection.

Overall, 92 percent of bicyclists obeyed the traffic signals that were in place. There was little variation by type of facility. The result was different for stop signs, however. Overall, 75 percent of bicyclists obeyed the stop signs that were present. Proportionally more bicyclists in WCLs (45 percent) disobeyed signs than bicyclists in BLs (19 percent). Of 225 instances where a signal was disobeyed, 36 (16 percent) were considered somewhat unsafe and 5 (2 percent) definitely unsafe. There was no variation by type of facility. The stop sign situation again produced a different outcome. Of 220 instances where a stop sign was disobeyed, 29 (13 percent) were considered somewhat unsafe and 4 (2 percent) definitely unsafe. However, the proportion of bicyclists with somewhat unsafe (19 versus 5 percent) and definitely unsafe (3 versus 0 percent) movements was higher in the BL facilities. A statistically significant difference was detected when the somewhat unsafe and definitely unsafe categories were combined.þ

Almost 72 percent of the bicyclists went straight through the intersection, with another 15 percent turning left and 13 percent turning right (table 10). There was little variation by type of facility. Of the 17 cyclists who walked their bike through the intersection, 12 were in WCLs.

Of the 2,700+ bicyclists who went straight through the intersections, 27 percent went from BL to BL, 17 percent from WCL to WCL, 4 percent from WCL to another traffic lane, 25 percent maneuvered like a motor vehicle in a traffic lane, and 4 percent used the marked crosswalk. Another 2 percent switched to the sidewalk and then crossed on the marked crosswalk. Some 3 percent went straight through from a right turn lane, and another 10 percent used some other method, such as BL to traffic lane or from left side of right turn lane. The 10 percent using another method of going straight through included 14 percent in WCLs and 8 percent in BLs. (No statistical test of the distributions was performed due to exclusive BL and WCL movements.) Nine percent of the cyclists tended to shy to the right (i.e., move to the right and away from traffic) as they went through the intersection (11 percent in BLs and 7 percent in WCLs). Interestingly, more than twice as many WCL users (17 percent) exited to a sidewalk or path beside the roadway than BL users (6 percent) (no table shown).

Depending on a number of factors, such as multiple lanes and the speed and volume of motor vehicle traffic, left turns at intersections can pose problems for bicyclists. The types of left turns that were videotaped bear this out. There were problems in making left turns from both BLs and WCLs.

Table 10. Intersection movements.

Bicyclist Direction	BLs	WCLs	Total
Straight	1646 (72.2)	1078 (70.9)	2724 (71.7)
Left	308 (13.5)	243 (16.0)	551 (14.5)
Right	312 (13.7)	187 (12.3)	499 (13.1)
Other	13 (0.6)	13 (0.9)	26 (0.7)
Total	2279 (60.0)	1521 (40.0)	3800 (100.0)

Bicyclist Walked Bike?**	BLs	WCLs	Total
Yes	5 (0.2)	12 (0.6)	17 (0.4)
No	2620 (99.8)	1905 (99.4)	4525 (99.6)
Total	2625 (57.8)	1917 (42.2)	4542 (100.0)

** $p < .01$

Bicyclist Straight Through Method	BLs	WCLs	Total
Straight from BL to BL	732 (44.4)	0 (0.0)	732 (26.8)
BL to traffic lane	210 (12.7)	0 (0.0)	210 (7.7)
WCL to WCL	0 (0.0)	478 (44.3)	478 (17.5)
WCL to traffic lane	0 (0.0)	116 (10.8)	116 (4.3)
Like motor vehicle in traffic lane	455 (27.6)	215 (19.9)	670 (24.6)
In street but on crosswalk	67 (4.1)	43 (4.0)	110 (4.0)
Moved to sidewalk & then to crosswalk	19 (1.2)	37 (3.4)	56 (2.1)
Straight from right turn lane	41 (2.5)	33 (3.1)	74 (2.7)
Other	126 (7.6)	156 (14.5)	282 (10.3)

Bicyclist Tracking***	BLs	WCLs	Total
Straight	1445 (88.9)	941 (93.0)	2386 (90.5)
Shy to right	173 (10.6)	70 (6.9)	243 (9.2)
Shy to left	8 (0.5)	1 (0.1)	9 (0.3)
Total	1626 (61.6)	1012 (38.4)	2638 (100.0)

*** $p < .001$

Level of Significance
* $p < .05$
** $p < .01$
*** $p < .001$

Of the 550 bicyclists making left turns at the intersections (table 11), 44 percent did so like a motor vehicle with proper lane destination positioning (41 percent from BLs and 48 percent from WCLs). Another 8 percent made motor vehicle style left turns but with improper lane destination positioning (3 percent from BLs and 14 percent from WCLs). Almost 17 percent of the cyclists made pedestrian style left turns, where the cyclist would ride all the way to the intersection and then use the crosswalk to get across the street like a pedestrian.

Table 11. Intersection turning information.

Bicyclist Left Turn Method	BLs	WCLs	Total
Motor vehicle style - proper destination positioning	126 (41.0)	116 (47.9)	242 (44.1)
Motor vehicle style - improper destination positioning	10 (3.3)	34 (14.1)	44 (8.0)
Pedestrian style - near side of intersection	26 (8.5)	40 (16.5)	66 (12.0)
Pedestrian style - far side of intersection	10 (3.3)	17 (7.0)	27 (4.9)
Right hook	19 (6.2)	2 (0.8)	21 (3.8)
Left from BL	88 (28.7)	0 (0.0)	88 (16.0)
Advance crossover	10 (3.3)	14 (5.8)	24 (4.4)
Motor vehicle-pedestrian combination	15 (4.9)	14 (5.8)	29 (5.3)
Other	3 (1.0)	5 (2.1)	8 (1.5)
Total	307 (55.9)	242 (44.1)	549 (100.0)

Bicyclist Right Turn Method**	BLs	WCLs	Total
Standard	277 (89.9)	154 (81.1)	431 (86.6)
Non-standard	31 (10.1)	36 (19.0)	67 (13.5)
Total	308 (61.9)	190 (38.2)	498 (100.0)

** $p < .01$

Level of Significance

* $p < .05$

** $p < .01$

*** $p < .001$

Twelve percent crossed on the near side, and 5 percent on the far side, of the intersection. Proportionally more cyclists made these pedestrian style left turns from WCLs. Of the 4 percent who turned right to allow a motor vehicle to pass before executing a u-turn (a “right hook” left turn), the vast majority were in BLs. Overall, 16 percent of the bicyclists made left turns from the BL (29 percent of the bicyclists in BLs made left turns from the BL, but the vast majority occurred at a single site, a t-intersection, where most of the motor vehicle and bicycle traffic made left turns).No statistical test of the distributions was made because of this exclusive BL maneuver. Finally, 4 percent made an advance crossover before reaching the intersection proper, and 5 percent made a combination motor vehicle-pedestrian left turn (such as approaching the intersection in a left turn lane and then using the crosswalk to complete the turn). Upon completing the left turn, 21 percent of the cyclists on WCLs exited to a sidewalk or path beside the road, compared with 15 percent of the cyclists on BLs (not shown in table).

For bicyclists making motor vehicle style left turns, the distance back from the stop bar that the cyclist started to merge to the left was coded. Where BLs were present, more than half of the cyclists merged left in the last 60 m. Where WCLs were present, about half of the cyclists merged left in the last 30 m. The median value was 63 m for BLs and 35 m for WCLs. Seventeen percent of the cyclists merging left and making these motor vehicle style left turns were considered to have incorrect lane position through the maneuver (11 percent from BLs and 23 percent from WCLs — not shown in table).

Almost 500 bicyclists made right turns at the intersections, and 87 percent were judged to have done so correctly (or in a standard fashion), and 13 percent in a non-standard fashion (e.g., from BL or WCL/traffic lane to wrong way position on cross street, or from BL or WCL/traffic lane to sidewalk). Bicyclists in WCLs were more likely to make right turns in a non-standard manner (19 percent in WCLs and 10 percent in BLs).þ Such turns included the use of the sidewalk and going through parking lots or yards. Upon completing the right turn, approximately 15 percent of the cyclists at both BL and WCL sites exited to a sidewalk or path beside the road (not shown in table).

Behaviors

Similar to the midblock area, various behaviors in the intersection were coded. Table 12 shows a list of behaviors distributed by whether a BL or WCL site. Some grouping of behaviors has been performed to allow valid statistical comparisons. Specific behaviors seen proportionally more often in BLs than WCLs included:

- The bicyclist not stopping at a stop sign (only slightly higher than for WCL).
- The bicyclist having to slow/stop/swerve due to traffic *not* influenced by the intersection ahead (e.g., a motor vehicle pulling into the BL from a driveway).
- Bicyclist encounters with other bicyclists (low frequencies).

Behaviors seen proportionally more often in WCLs included:

- The bicyclist not stopping at a traffic signal (only slightly higher than for BL).
- Improper lane use by the bicyclist.
- The bicyclist having to slow/stop/swerve due to intersection traffic.
- The bicyclist turning or swerving across a lane of traffic.
- The bicyclist passing slow or stopped vehicles on the rightþ (Note: this could be coded in a BL situation when the BL stripe was terminated or dashed to the intersection).
- Bicyclists riding two abreast (low frequencies).
- Bicyclist encounters with pedestrians.
- “Other” types of behaviors.

Examples of the “other” kinds of bicyclist behaviors (low frequencies of each) included turning left from the right side of the traffic lane, right on red maneuvers, and walking the bicycle.

When any of the intersection behaviors were observed, a code was used to denote whether there was a motor vehicle in the vicinity, obviously implying that the behaviors were potentially more dangerous if this were the case. “In the vicinity” was defined as within approximately 66 m. Overall, vehicles were in the vicinity 83 percent of the time (85 percent at BL sites versus 80 percent at WCL sites).þ

The next part of table 12, “Midblock Behaviors with a Motor Vehicle in the Vicinity,” amplifies the information above by allowing specific comparisons for the behaviors. For example, of the 81 bicyclists who turned or swerved across a lane of traffic, 66 did so with a motor vehicle in the vicinity.

Table 12. Intersection behaviors.

Behavior* **	BLs	WCLs	Total
None	1929 (81.1)	1140 (70.9)	3069 (77.0)
Bike did not stop for stop sign	140 (5.9)	91 (5.7)	231 (5.8)
Bike did not stop for traffic signal	76 (3.2)	60 (3.7)	136 (3.4)
Bike improper lane use	12 (0.5)	30 (1.9)	42 (1.1)
Bike slowed/stopped/swerved for intersection traffic	25 (1.1)	26 (1.6)	51 (1.3)
Bike slowed/stopped/swerved for traffic not at intersection	21 (0.9)	7 (0.4)	28 (0.7)
Bike turned or swerved across a lane of traffic	39 (1.6)	42 (2.6)	81 (2.0)
Bike passed slow or stopped vehicle on right	31 (1.3)	86 (5.4)	117 (2.9)
Bike stunt riding	14 (0.6)	11 (0.7)	25 (0.6)
Bikes riding two abreast	4 (0.2)	10 (0.6)	14 (0.4)
Bike encounter with pedestrian	7 (0.3)	18 (1.1)	25 (0.6)
Bike encounter with another bike	9 (0.4)	2 (0.1)	11 (0.3)
Other behaviors	71 (3.0)	85 (5.3)	156 (3.9)
Total	2378 (59.7)	1608 (40.3)	3986 (100.0)

*** p < .001

Vehicle in Vicinity for Intersection Behaviors* **	BLs	WCLs	Total
Yes	2238 (84.9)	1539 (80.3)	3777 (83.0)
No	398 (15.1)	377 (19.7)	775 (17.0)
Total	2636 (57.9)	1916 (42.1)	4552 (100.0)

*** p < .001

Level of Significance
* p < .05
** p < .01
*** p < .001

Table 12. Intersection behaviors (con't).

Intersection Behaviors with a Motor Vehicle in the Vicinity***	BLs	WCLs	Total
None	1690 (81.6)	1042 (74.1)	2732 (78.6)
Bike did not stop for stop sign	94 (4.5)	32 (2.3)	126 (3.6)
Bike did not stop for traffic signal	71 (3.4)	52 (3.7)	123 (3.5)
Bike improper lane use	10 (0.5)	29 (2.1)	39 (1.1)
Bike slowed/stopped/ swerved for intersection traffic	25 (1.2)	25 (1.8)	50 (1.4)
Bike slowed/stopped/ swerved for traffic not at intersection	20 (1.0)	7 (0.5)	27 (0.8)
Bike turned or swerved across a lane of traffic	32 (1.5)	34 (2.4)	66 (1.9)
Bike passed slow or stopped vehicle on right	31 (1.5)	85 (6.1)	116 (3.3)
Bike stunt riding	13 (0.6)	10 (0.7)	23 (0.7)
Bikes riding two abreast	4 (0.2)	8 (0.6)	12 (0.4)
Bike encounter with pedestrian	5 (0.2)	16 (1.1)	21 (0.6)
Bike encounter with another bike	9 (0.4)	2 (0.1)	11 (0.3)
Other behaviors	68 (3.3)	64 (4.6)	132 (3.8)
Total	2072 (59.6)	1406 (40.4)	3478 (100.0)

*** p < .001

Level of Significance
* p < .05
** p < .01
*** p < .001

Conflicts

Midblock

A conflict was defined as an interaction between a bicycle and motor vehicle, pedestrian, or other bicycle such that at least one of the parties had to change speed or direction to avoid the other. There were 188 conflicts in the midblock area, and totals less than this in the tables that follow are due to missing values. The conflicts in the midblock area were of the following type (table 13):

- 71 percent bicycle/motor vehicle.
- 10 percent bicycle/bicycle.
- 19 percent bicycle/pedestrian.

Almost all of the bike/bike conflicts occurred in BLs. Compared with BLs, bicyclists in WCLs experienced more bike/pedestrian conflicts (30 versus 16 percent)þ and less bike/bike conflicts (2.5 versus 12 percent).

A scale was used to code level of avoidance response for both bicycles and motor vehicles (but not for pedestrians). The scale for bicycles was used in a study of painted bike crossings at intersections in Canada (Pronovost and Lusginan, 1996) and had the following categories:

- No change in riding.
- Stops pedaling.
- Slight change of direction.
- Applies brakes.
- Major change of direction.
- Full stop.
- Collision or near crash.

Examining the full distribution for the midblock conflicts shows that BL users had proportionally more minor responses, such as stopping pedaling and slight change of direction. Conversely, WCL users had proportionally more serious responses, such as braking, major change of direction, and full stop. In the midblock area, there were no instances of collisions/near crashes. After combining several categories to enable a valid chi-square test, no significant differences in the BL and WCL distributions were found.

Table 13. Midblock conflict information.

Conflict Type*	BLs	WCLs	Total
Bike/motor vehicle	99 (71.7)	27 (67.5)	126 (70.8)
Bike/bike	17 (12.3)	1 (2.5)	18 (10.1)
Bike/ped	22 (15.9)	12 (30.0)	34 (19.1)
Total	138 (77.5)	40 (22.5)	178 (100.0)

* p < .05

Bicycle Avoidance Response	BLs	WCLs	Total
No change in riding	4 (2.8)	5 (12.2)	9 (4.9)
Stops pedaling	12 (8.4)	2 (4.9)	14 (7.6)
Slight change of direction	98 (68.5)	19 (46.3)	117 (63.6)
Applies brakes	10 (7.0)	4 (9.8)	14 (7.6)
Major change of direction	17 (11.9)	8 (19.5)	25 (13.6)
Full stop	2 (1.4)	3 (7.3)	5 (2.7)
Total	143 (77.7)	41 (22.3)	184 (100.0)

Motor Vehicle Driver Avoidance Response	BLs	WCLs	Total
No change in driving	98 (78.4)	21 (75.0)	119 (77.8)
Slows	10 (8.0)	2 (7.1)	12 (7.8)
Slight change of direction	5 (4.0)	2 (7.1)	7 (4.6)
Applies brakes	2 (1.6)	0 (0.0)	2 (1.3)
Major change of direction	1 (0.8)	1 (3.6)	2 (1.3)
Full stop	9 (7.2)	2 (7.1)	11 (7.2)
Total	125 (81.7)	28 (18.3)	153 (100.0)

Seriousness of Conflict	BLs	WCLs	Total
Minor	140 (98.6)	38 (97.4)	178 (98.3)
Serious	2 (1.4)	1 (2.6)	3 (1.7)
Total	142 (78.5)	39 (21.6)	181 (100.0)

Level of Significance
* p < .05
** p < .01
*** p < .001

The motor vehicle scale was created for the current project and used similar categories:

- No change in driving.
- Slows.
- Slight change of direction.
- Applies brakes.
- Major change of direction.
- Full stop.
- Collision or near crash.

There was little variation in the BL and WCL distributions. Categories were again combined to enable a valid chi-square test, and no significant difference in the BL and WCL distributions was found.

The distributions were examined further by utilizing the level of the scale (1 for no change in riding, 2 for stops pedaling, etc.) to develop a mean value for the responses. For the bicycle avoidance response, the BL mean was 3.21 and the WCL mean was 3.41. Using a t-test to examine the hypothesis of no difference between the means, the difference was not statistically significant.

The seriousness of the conflicts was coded as minor, serious, or unsure. In the midblock area, 98 percent of the conflicts were coded as minor in nature, and there were no differences in the BL and WCL distributions.

Bicycle actions more associated with BLs in these midblock conflicts (table 14) included: The motor vehicle avoidance responses were similarly compared. The BL mean was 1.60 and the WCL mean 1.71. Once again the difference was insignificant.

Table 14. Midblock conflict bicycle and motor vehicle actions.

Bike Actions in Midblock Conflicts* **	BLs	WCLs	Total
None	6 (4.4)	10 (25.0)	16 (9.0)
Bike slowed/stopped/swerved for traffic not at intersection	85 (62.0)	15 (37.5)	100 (56.5)
Bike turned or swerved across a lane of traffic	14 (10.2)	1 (2.5)	15 (8.5)
Bike encounter with pedestrian	12 (8.8)	11 (27.5)	23 (13.0)
Bike encounter with bicyclist	5 (3.7)	0 (0.0)	5 (2.8)
Other bike actions	15 (11.0)	3 (7.5)	18 (10.2)
Total	137 (77.4)	40 (22.6)	177 (100.0)

*** p < .001

Motor Vehicle Actions in Midblock Conflicts **	BLs	WCLs	Total
None	31 (25.4)	3 (9.1)	34 (21.9)
Motor vehicle turned right in front of bike after overtaking	6 (4.9)	3 (9.1)	9 (5.8)
Motor vehicle illegally parked in BL/WCL	29 (23.8)	2 (6.1)	31 (20.0)
Motor vehicle entering/exiting on-street parking or driver/passenger entering or exiting a parked or stopped vehicle	19 (15.6)	4 (12.1)	23 (14.8)
Other motor vehicle actions	37 (30.3)	21 (63.6)	58 (37.4)
Total	122 (78.7)	33 (21.3)	155 (100.0)

** p < .01

Level of Significance
* p < .05
** p < .01
*** p < .001

- The bicycle slowing/stopping/ swerving for traffic not influenced by the intersection.
- The bicycle turning or swerving across a lane of traffic.
- Encounters with other bicyclists.
- "Other" actions.

Examples of the "other" kinds of bicyclist actions (low frequencies of each) included improper left turns and passing slow moving or stopped motor vehicles on the right (sometimes occurred at a BL site after the BL stripe was terminated or dashed to the intersection, or where a bicyclist was turning right in a right turn lane).

Bicycle actions more associated with WCLs included:

- No action takenþ.
- Encounters with pedestriansþ.

Motor vehicle actions more associated with BLs included:

- No action taken.
- Illegally parked in the BL.
- Entering/exiting on-street parking or driver or passenger entering/exiting a parked or stopped vehicleþ.

(Note: The statistical contributions to the overall chi-square value noted for BLs above are actually due to *less* of the actions in WCLs than expected.)

Motor vehicle actions more associated with WCLs included:

- Turning right in front of a bicyclist after overtaking.
- "Other" actionsþ.

Examples of the "other" kinds of motor vehicle actions (low frequencies of each) included failure to yield, improper right turns, and crowding bikes.

Intersections

There were 198 conflicts in the intersection area, and totals less than this in the tables that follow are due to missing values. The conflicts in the intersection area were of the following type (table 15):

- 79 percent bicycle/motor vehicle.
- 10 percent bicycle/bicycle.
- 10 percent bicycle/pedestrian.

The differences in the BL/WCL distributions were statistically significant. There were proportionally more bike/bike conflicts in BLs (15 percent) and less in WCLs (4 percent). Conversely, there were proportionally more bike/pedestrian conflicts in WCLs (17 percent) and less in BLs (6 percent).

For the intersection conflicts, the position of the motor vehicle with respect to the bicyclist was coded. Overall, 66 percent of the motor vehicles were traveling in the same direction, 6 percent in the opposing direction, 5 percent approaching from the left, 15 percent approaching from the right, and 7 percent from some other position. Proportionally more BL conflicts involved motor vehicles from the same direction and cross street traffic from the right. Proportionally more WCL conflicts involved motor vehicles from the opposing direction, cross street traffic from the left, and traffic from some other position. The differences by type of facility were not statistically significant (cross street traffic from right and left combined for statistical test).

There was variability in the position of the motor vehicle depending on the maneuver of the bicyclist (no table shown). For example, when the bicyclist went straight through the intersection (82 cases), the motor vehicle position was:

- Same direction - 77 percent of conflicts.

Table 15. Intersection conflict information.

Conflict Type*	BLs	WCLs	Total
Bike/motor vehicle	78 (78.8)	72 (78.3)	150 (78.5)
Bike/bike	15 (15.2)	4 (4.4)	19 (10.0)
Bike/pedestrian	6 (6.1)	16 (17.4)	22 (10.0)
Total	99 (51.8)	92 (48.2)	191 (100.0)

* p < .05

Biycle Avoidance Response	BLs	WCLs	Total
No change in riding	11 (10.6)	11 (12.5)	22 (11.5)
Stops pedaling	12 (11.5)	17 (19.3)	29 (15.1)
Slight change of direction	53 (51.0)	33 (37.5)	86 (44.8)
Applies brakes	11 (10.6)	7 (8.0)	18 (9.4)
Major change of direction	9 (8.7)	9 (10.2)	18 (9.4)
Full stop	8 (7.7)	9 (10.2)	17 (8.9)
Collision or near crash	0 (0.0)	2 (2.3)	2 (1.0)
Total	104 (54.2)	88 (45.8)	192 (100.0)

Motor Vehicle Position	BLs	WCLs	Total
Same direction as bike	68 (73.1)	40 (57.1)	108 (66.3)
Opposing direction to bike	3 (3.2)	7 (10.0)	10 (6.1)
Cross street from left	3 (3.2)	5 (7.1)	8 (4.9)
Cross street from right	15 (16.1)	10 (14.3)	25 (15.3)
Other	4 (4.3)	8 (11.4)	12 (7.4)
Total	93 (57.1)	70 (42.9)	163 (100.0)

Motor Vehicle Driver Avoidance Response	BLs	WCLs	Total
No change in driving	61 (64.9)	43 (60.6)	104 (63.0)
Slows	19 (20.2)	8 (11.3)	27 (16.4)
Slight change of direction	5 (5.3)	9 (12.7)	14 (8.5)
Applies brakes	3 (3.2)	5 (7.0)	8 (4.9)
Major change of direction	0 (0.0)	1 (1.4)	1 (0.6)
Full stop	6 (6.4)	5 (7.0)	11 (6.7)
Total	94 (57.0)	71 (43.0)	165 (100.0)

Seriousness of Intersection Conflict	BLs	WCLs	Total
Minor	92 (93.9)	84 (91.3)	176 (92.6)
Serious	6 (6.1)	8 (8.7)	14 (7.4)
Total	98 (51.6)	92 (48.4)	190 (100.0)

Level of Significance
* p < .05
** p < .01
*** p < .001

- Opposing direction - 4 percent of conflicts.
- Cross street from left - 2 percent of conflicts.
- Cross street from right - 11 percent of conflicts.
- Other position - 6 percent of conflicts.

When the bicyclist made a left turn (24 cases), the motor vehicle position was:

- Same direction - 42 percent of conflicts.
- Opposing direction - 17 percent of conflicts.
- Cross street from left - 13 percent of conflicts.
- Cross street from right - 21 percent of conflicts.
- Other position - 8 percent of conflicts.

When the bicycle made a right turn at the intersection (8 cases), the motor vehicle position was:

- Same direction - 63 percent of conflicts (5 cases).
- Opposing direction - 0 percent of conflicts.
- Cross street from left - 13 percent of conflicts (1 case).
- Cross street from right - 0 percent of conflicts.
- Other position - 25 percent of conflicts (2 cases).

Similar to midblock conflicts, the avoidance response scale for both bicycles and motor vehicles was used at intersections. Examining the full distribution for the intersection conflicts shows that bicyclists in WCLs had proportionally more of the serious responses, such as major direction changes, full stops, and near collisions; however, there were no significant differences in the distributions.

In regard to the motor vehicle avoidance response scale, there was little variation in the BL and WCL distributions. Categories were combined to enable a valid chi-square test, and no significant differences in the BL and WCL distributions were found.

The distributions were examined further by utilizing the level of the scale (1 for no change in riding, 2 for stops pedaling, etc.) to develop a mean value for the responses. For the bicycle avoidance response, the BL mean was 3.18 and the WCL mean was 3.24. Using a t-test to examine the hypothesis of no difference between the means, the difference was not statistically significant.

The motor vehicle avoidance responses were similarly compared. The BL mean was 1.72 and the WCL mean 1.99, and the difference was insignificant.

The seriousness of the conflicts was coded as before. In the intersection area, 93 percent of the conflicts were coded as minor in nature, and there were no differences in the BL and WCL distributions.

Bicycle actions more associated with BLs in these intersection conflicts (table 16) included:

- The bicycle slowing/stopping/ swerving for intersection traffic.
- The bicycle slowing/stopping/ swerving for traffic not influenced by the intersectionþ.
- The bicycle turning or swerving across a lane of traffic.

Bicycle actions more associated with WCLs included:

- No action taken.
- Passing slow moving or stopped motor vehicles on the right.
- Encounters with pedestrians.
- “Other” actions.

Table 16. Intersection conflict bicycle and motor vehicle actions.

Bike Actions in Intersection Conflicts* **	BLs	WCLs	Total
None	8 (7.8)	10 (11.1)	18 (9.4)
Bike slowed/stopped/swerved for intersection traffic	30 (29.4)	22 (24.4)	52 (27.1)
Bike slowed/stopped/swerved for traffic not at intersection	37 (36.3)	8 (8.9)	45 (23.4)
Bike turned or swerved across a lane of traffic	7 (6.9)	4 (4.4)	11 (5.7)
Bike passed slow or stopped vehicle on right	0 (0.0)	10 (11.1)	10 (5.2)
Encounter with pedestrian	2 (2.0)	16 (17.8)	18 (9.4)
Other bike actions	18 (17.7)	20 (22.2)	38 (19.8)
Total	102 (53.1)	90 (46.9)	192 (100.0)

*** $p < .001$

Motor Vehicle Actions in Intersection Conflicts	BLs	WCLs	Total
None	36 (37.5)	28 (43.1)	64 (39.8)
Motor vehicle slowed/stopped/ swerved for intersection traffic	11 (11.5)	12 (18.5)	23 (14.3)
Motor vehicle turned right in front of bike after overtaking	4 (4.2)	7 (10.8)	11 (6.8)
Motor vehicle illegally parked in BL/WCL	7 (7.3)	1 (1.5)	8 (5.0)
Motor vehicle entering/exiting on-street parking	10 (10.4)	6 (9.2)	16 (9.9)
Other motor vehicle actions	28 (29.2)	11 (16.9)	39 (24.2)
Total	96 (59.6)	65 (40.4)	161 (100.0)

Level of Significance
* $p < .05$ ** $p < .01$ *** $p < .001$

Examples of the "other" kinds of bicyclist actions (low frequencies of each) included improper left turns, merging onto the road from a sidewalk, and stunt riding.

Motor vehicle actions more associated with BLs in these intersection conflicts included:

- Illegally parked in the BL.
- Entering/exiting on-street parking.
- "Other" motor vehicle actions.

Examples of the "other" kinds of motor vehicle actions (low frequencies of each) included a driver or passenger entering or exiting a parked or stopped vehicle, and crowding of the BL or edge of travel lane. Motor vehicle actions more associated with WCLs included:

- No action taken.
- Slowing/stopping/swerving for intersection traffic.

- Turning right in front of a bicyclist after overtaking.

Midblock and intersection combined conflict rates

Combining the number of conflicts in both the midblock and intersection areas resulted in a total of 237 conflicts at BL sites and 132 at WCL sites. Conflict rates per entering bicyclist by type of facility were the following:

<u>All Conflicts (Bike/motor vehicle, bike/bike, and bike/pedestrian)</u>

BL sites: 237 conflicts/2,657 bicyclists = 8.9 conflicts per 100 entering bicyclists
WCL sites: 32 conflicts/1,932 bicyclists = 6.8 conflicts per 100 entering bicyclists

<u>Bike/Motor Vehicle Conflicts</u>

BL sites: 177 conflicts/2,657 bicyclists = 6.7 conflicts per 100 entering bicyclists
WCL sites: 99 conflicts/1,932 bicyclists = 5.1 conflicts per 100 entering bicyclists

Thus, BL sites had slightly higher rates of conflicts than WCL sites. Examining the bike/motor vehicle rates shows that more than 6 percent of the bicyclists riding through the project sites had a conflict with a motor vehicle. These raw frequency results are more thoroughly explored in the statistical modeling section that follows.

Statistical Modeling of Conflicts Data

Analysis of midblock bike/motor vehicle conflicts

Each bicyclist observed in the midblock area was coded as being involved in no bike/motor vehicle conflicts or as being involved in one or more such conflicts. Overall, out of 4,342 observed bicyclists, 4,222 (97.2 percent) had no conflicts, 114 (2.6 percent) had 1 conflict, and 6 (.001 percent) had 2 conflicts. For bicyclists in WCLs and BLs, the percentages were 98.5, 1.5, and 0 versus 96.4, 3.4, and 0.2 percent, respectively. Thus, the rate of midblock bike/ motor vehicle conflicts associated with BLs was more than double that associated with WCLs for these small percentages. However, as explained below, this differ- ence cannot be directly or fully attributed to the type of facility. The analyses that follow represent an attempt to identify other factors that are associated with these conflicts and that may account for some of the observed differences.

As noted earlier, a number of bicyclists turned left or right prior to reaching the intersection. In particular, 130 bicyclists crossed to the left before the intersection and 12 were involved in bike/motor vehicle conflicts. All 12 were associated with two particular BL sites that are examined in depth clinically in a subsequent section of this chapter.

Using data from those bicyclists *not turning left* prior to the intersection, a generalized linear model was developed to explore relationships between conflicts and factors associated with site geometrics, motor vehicle traffic, bicyclist characteristics, etc. In this type of model, the number of midblock bike/motor vehicle conflicts (for a given bicyclist) was taken as the response or dependent variable, y, which was assumed to follow a Poisson distribution with mean μ. It was further assumed that the function

$$\log(\mu) = \beta_o + \sum_{j=1}^{N} \beta_j X_j ,$$

where $X_1, X_2, \ldots, X_N$, are the explanatory variables of interest and the β's are unknown coefficients estimated by fitting the model to data. Significance tests of the β's show which variables are important and how they relate to conflicts. An example of the results of fitting such a model is given in table 17.

Table 17. Example of model results for midblock conflicts.

Variable	estimate (þ)	P-value
Constant	-4.892	.0001
Traffic volume (vph)	.001	.0058
Driveways	.291	.0263
Bike lane	1.053	.0001
Parked vehicles	-.294	.2685

The model of table 17 contains four explanatory variables: an hourly count of motor vehicle traffic traveling in the same direction as the bicycle, number of intersecting driveways in the midblock area, a variable indicating the presence of a BL, and a variable indicating that the bike is being ridden beside parked vehicles. The p-values show that the first three variables are statistically significant while the fourth is not. The magnitude and algebraic sign of the estimated
the relationships between mean conflicts and the explanatory variables. Thus, the positive estimate for the BL indicator variable shows that even with the other variables taken into account, the mean number of midblock conflicts is still greater in BLs than in WCLs.

Model development was continued by deleting non-significant variables, such as presence of parked vehicles, and trying other potential explanatory variables in the model. A number of other variables such as number of midblock intersecting streets; estimated vehicle speed; number of lanes; bicycle compatibility index (BCI);[4] bicyclist age and gender; and bicyclist experience level (a site specific variable based on the results of the oral survey) were examined in the model and were also found *not* to be significantly related to midblock bike/motor vehicle conflicts. An additional variable that did appear to be significantly associated with conflicts was BL width. Including this variable in the model produced the results shown in table 18.

Table 18. Midblock conflicts model including bike lane width.

Variable	estimate (þ)	P-value
Constant	-5.009	.0001
Traffic volume (vph)	.001	.0121
Driveways	.508	.0005
Bike lane	3.094	.0001
BL width (m)	-1.22	.0001

The BL indicator variable is coded as zero when no BL is present, and one when a BL is present. BL width was coded as zero when no BL was present, and the actual width (which varies from 1.2 to 2.9 m) when a BL was present. Thus, the last two variables in the model contribute the amount

$$w = 3.094 - 1.22 \text{ BL width}$$

to the linear expression for log (μ) when a BL is present. This indicates that, for BLs with widths less than 2.5 m, w_B is positive and the likelihood of a bike/motor vehicle conflict is greater for the BL than for the

[4] The BCI is a tool that can be used to assess the “bicycle friendliness” of a roadway. Variables used to develop the BCI for a roadway include a number of geometric and operational characteristics (e.g., curb lane width, traffic volume, and vehicle speed). For more detail, see FHWA Report No. FHWA-RD- 98-072, *Development of the Bicycle Compatibility Index: A Level of Service Concept* (Harkey, Reinfurt, Knuiman, Stewart, and Sorton, 1998).

WCL. On the other hand, when the BL width is greater than 2.5 m, w_B is negative and the likelihood of a conflict is less for the BL than a comparable WCL. To examine these results in more detail, table 19 gives a tabulation of midblock conflicts corresponding to each specific BL width in the study. Note the 0.0 width category corresponds to all WCLs. From the table it is clear that the higher conflict rates correspond to some of the lowest BL widths. However, the widths of 1.4s and 1.59 m, which correspond to the highest conflict rates, represent one specific site each. Moreover, while four sites have widths of 1.22 m, the high conflict rate is again due to a single site, which contributes 257 observations and 21 conflicts. The basic question then is whether or not the higher conflict rates can really be attributed to the narrow BLs or to very specific characteristics of a few sites. These specific characteristics are examined in more detail in the clinical examination later in the chapter.

As another illustration of the difficulties in separating general relationships from specific site-related characteristics, two WCL sites were considered as being perhaps atypical in that some on-street parking occurred in the WCL during the videotaping. Although it can be argued that motor vehicles parking in a bicycle facility is a frequent “real-world” condition, it was thought that perhaps data from these sites should be excluded from the analyses. Sixty-two observations were available from the first site. This site had a high traffic volume (942 vehicles/h), 2 midblock driveways, and

Table 19. Bike lane width by midblock conflicts.

Bike Lane Width	Midblock Conflicts			Total
	0	1	2	
0.0	1857 (98.6)	27 (1.4)	0 (0.0)	1884
1.22	372 (93.7)	24 (6.1)	1 (0.3)	397
1.46	113 (89.7)	12 (9.5)	1 (0.8)	126
1.53	890 (97.6)	21 (2.3)	1 (0.1)	912
1.59	39 (90.7)	4 (9.3)	0 (0.0)	43
1.83	109 (99.1)	1 (0.9)	0 (0.0)	110
1.98	197 (100.0)	0 (0.0)	0 (0.0)	197
2.14	186 (97.9)	4 (2.1)	0 (0.0)	190
2.35	161 (96.4)	6 (3.6)	0 (0.0)	167
2.44	281 (98.9)	3 (1.1)	0 (0.0)	284
2.90	146 (98.0)	3 (2.0)	0 (0.0)	149
Total	4351	105	3	4459

a total of 9 midblock bike/motor vehicle conflicts. The second site had a relatively low traffic volume (193 vehicles/h), 1 mid-block driveway, and 1 conflict in 50 observations. When these 112 observations were deleted from the data set and the model of table 18 refitted to the remaining data, both the estimated traffic volume and driveway effects became nonsignificant, (p = 0.126 and p = 0.176, respectively). Factors such as traffic volume and presence of driveways would seem to be logically related to the occurrence of bike/motor vehicle conflicts since the opportunities for such conflicts should increase with increasing values of these factors. With a limited number of sites representing a wide variety of configurations, however, it is very difficult to determine statistically the exact nature of these relationships. Thus, some clinical analysis was necessary to examine high conflict rate sites in detail and gain a better understanding of any differences between BLs and WCLs.

Intersection bike/motor vehicle conflicts

For those bicyclists who continued on to the intersection, table 20 shows a tabulation of bike/motor vehicle conflicts in the intersection area as a function of facility type (BL or WCL) and the bicycle movement at the intersection. The table shows intersection conflict rates to be very similar for BLs and WCLs, and, in fact, when the two factors (facility type and intersection movement) were included in a model, facility type was not statistically significant (p = 0.339) while movement was (p = 0.010). More specifically, bicycle left turn movements were associated with higher conflict rates than right-turn or straight-through movements.

In addition to simply noting whether the facility was a BL or WCL, five different facility types were defined based on the nature of the BL or WCL at the intersection (figure 16) as shown below:

Type 1: BL striping continued to intersection (one site also had a bike pocket),

Type 2: BL terminated prior to intersection,

Type 3: BL dashed to intersection (again one site had a bike pocket).

Type 4: WCL continued to intersection,

Type 5: WCL narrowed (due to turn lanes, etc.) at intersection.

Table 20. Intersection conflicts by facility type and bicyclist movement.

Intersection Movement	Facility Type	Intersection Conflicts			
		0	1	2	Total
Straight Through	WCL	985 (96.4)	36 (3.5)	1 (0.1)	1022
	BL	1544 (97.0)	47 (2.9)	1 (0.1)	1592
Left Turn	WCL	206 (95.0)	7 (3.2)	4 (1.8)	217
	BL	284 (95.3)	14 (4.7)	0 (0.0)	298
Right Turn	WCL	160 (98.8)	2 (1.2)	0 (0.0)	162
	BL	297 (98.0)	6 (2.0)	0 (0.0)	303

No separate types were considered for bike pockets since these only occurred at two sites having different types of striping. When this new five-level type variable was included in a model for intersection conflicts along with intersection movement, both factors were significant (p = 0.0004 for type and p = 0.0017 for movement). Separate models were then estimated for left-turning bikes and for those going straight or right. For left-turning bikes, the five-level type factor was not significant (p = 0.3580). However, the conflict rate for type 1 intersections (BL stripe continued to intersections) was lower than that for the other types combined, at a level approaching significance, p = 0.0646. Ninety-seven percent of the bikes in left-turn movements from type 1 intersec- tions had no conflicts versus 94.2 percent from the other types combined.

For bicycles going straight or turning right, the five-level type factor was significant (p = 0.0013). In particular, types 1 and 4, where the BL or WCL was unchanged to the intersection, tended to be associated with significantly lower conflict rates than the other three types. Conflict frequencies and rates for bikes traveling straight through the intersection or making right turns are shown in table 21 for the five intersection types.

Attempts were made to include a number of other variables that might seem to be logically related to intersection conflicts such as motor vehicle traffic volumes and speeds, number of driveways in the intersection area (i.e., within 90 m of the intersection stop bar), bicyclist experience level, etc., into the models. None of the geometric or traffic variables were found to have significant or consistent meaningful relationships with intersection conflicts. However, bicyclist experience level, or more specifically the percentage of experienced bicyclists at a site, was statistically significant with a p-value of 0.0037. The estimated effect of this variable was -0.0275, indicating that the likelihood of intersection conflicts decreased as the percentage of experienced bicyclists increased. No other bicyclist variables (e.g., age and gender) were significant.

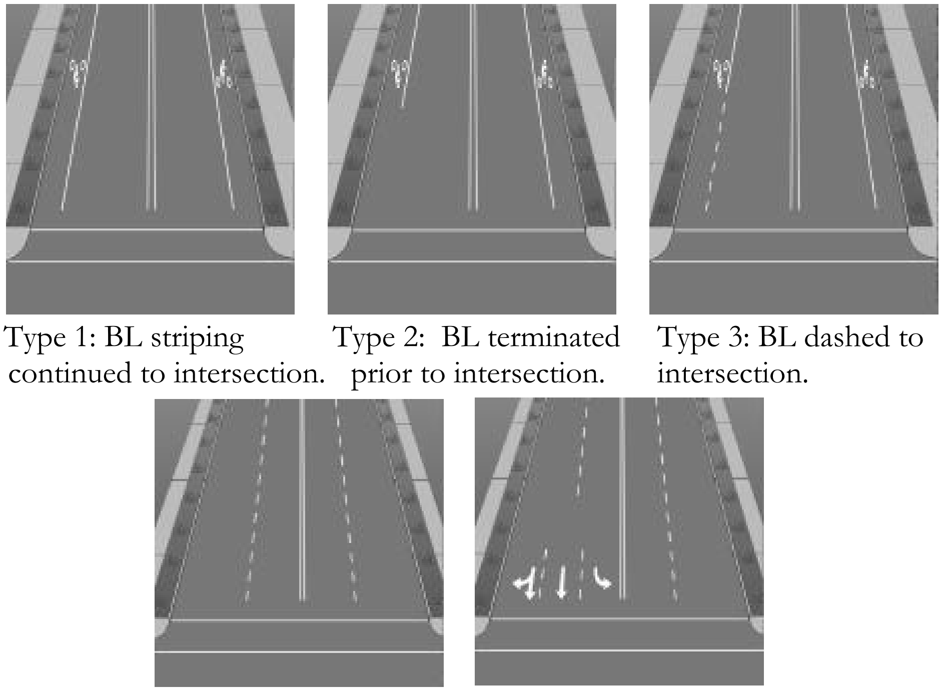


Figure 16. BL and WCL intersection types.

Table 21. Intersection conflicts by intersection type for straight through and right turning bicyclists.

Intersection Type	Intersection Conflicts			
	0.00	1	2	Total
BL continued to intersection	897 (98.4)	15 (1.6)	0 (0.0)	912
BL terminated prior to intersection	767 (96.1)	31 (3.9)	0 (0.0)	798
BL dashed to intersection	461 (95.5)	21 (4.4)	1 (0.2)	483
WCL unchanged at intersection	869 (97.4)	18 (2.0)	5 (0.6)	892
WCL narrowed at intersection	482 (94.7)	27 (5.3)	0 (0.0)	509
Total	3476	112	6	3594

Reanalysis of conflicts based on data from more "typical" sites

A reanalysis of the conflicts models was carried out using data from only 28 of the 48 sites. These 28 sites might be thought of as more "typical" of BL and WCL sites in the sense that sites with on-street parking as part of the bicycle facility were eliminated, as well as sites where the WCL was narrowed at the intersection due to the provision of turn lanes. The data from these 28 sites included 2,566 of the original 4,459 observations used in the midblock conflicts models. Sites 403 and 615, where motor vehicles parked in part of the WCL during the videotaping, were among the excluded sites, and earlier results had shown that eliminating these sites would eliminate the traffic volume and midblock driveway variables from the model. This was also the case with the reanalysis. Results from a midblock conflicts model fitted to the "typical" sites again showed that BL presence and BL width were significant variables.

Models for intersection bike/motor vehicle conflicts were also reanalyzed. With the non-typical sites excluded, the conflict rate for left-turning bicycles no longer differed significantly from the combined rate for bikes traveling straight through the intersection or making right turns. A model fitted to all bicycle intersection maneuvers (straight, left, and right) showed the conflict rate for type 3 intersections (BL dashed to intersection) to be significantly higher than for types 1 (BL striping carried to intersection), 2 (BL terminated prior to intersection), and 4 (WCL carried to intersection). Type 5 was non-typical and already eliminated. However, all the type 3 conflicts came from one busy intersection. There were no significant differences between conflict rates for types 1 and 4, but the conflict rate for type 2 was significantly higher than the rates for types 1 and 4. In addition, intersections with higher proportions of experienced bicyclists were significantly associated with lower intersection conflict rates.

The section of text that follows is a clinical examination of high rate conflict sites and offers some insight to the site-specific differences present in the data.

A Clinical Analysis of High Conflict BL and WCL Sites

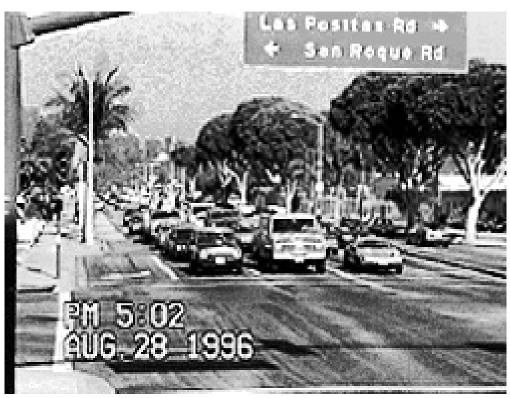
The lack of consistent results of the modeling efforts described in the preceding text forced a closer examination of the sites with the highest conflict rates (based on numbers of entering bicycles). What follows is a clinical or in-depth look at each of these sites to see if there were apparent factors or situations that led to the conflicts.

Midblock conflicts

1. Intersection of State and Las Positas - Santa Barbara, CA

- WCL site with turn lanes added at the intersection.
- 11 conflicts, 17.7 conflicts per 100 entering bicyclists.

State and Las Positas is an intersection in a



busy bicycle corridor in Santa Barbara. The intersection has four legs and is controlled by a traffic signal. The 5.2-m WCL is on State Street, which is four lanes, with AADT of 33,000. The estimated driving speed is 56 km/h. At the intersection, the two approaching lanes become five lanes. Beginning at the centerline, there is a double left turn lane, then two straight through lanes, and then a right turn lane added by widening the intersection. There are two intersecting driveways in the midblock area. Ninety-minute parking is allowed on the street, and vehicles sometimes park in the WCL, but the number of parked vehicles is generally small.

Of these 11 midblock conflicts, 9 were bike/motor vehicle. One of the nine was coded as serious in nature and one unsure. In the serious conflict the bicyclist turned or swerved across a lane of traffic as the motor vehicle was entering or exiting an on-street parking location. Five of the bike actions in the conflicts were having to slow, stop, or swerve for traffic *not* influenced by the intersection (e.g., a motor vehicle entering the roadway from a driveway), and in one instance a second bike action involved turning or swerving across a lane of traffic. In five other conflicts the bike action was "none" (i.e., no action detected). The most frequent motor vehicle actions were entering/exiting on-street parking and turning right after overtaking a bike.

There was one bike/pedestrian conflict, and the seriousness was minor.

The most prevalent midblock conflict problem for this location pertained to motor vehicles entering/exiting from on-street parking.

2. Intersection of State and Cabrillo - Santa Barbara, CA

- BL site with dashed stripe leading to the intersection.
- 45 conflicts, 16.2 conflicts per 100 entering bicyclists.

State and Cabrillo is an intersection in the tourist area of Santa Barbara. The intersection has four legs and is signal controlled, but the leg opposite the approaching BL is an entrance to a popular wharf that contains shops and restaurants. The 1.2-m BL is on State Street, which is four lanes, with AADT of 9,000. The estimated driving speed is 53 km/h. At the intersection, the two approaching lanes become three lanes. Beginning at the centerline, there is a left turn lane, then a left-and-through lane, and then a right turn lane. There is one intersecting street in the midblock area.

Of these midblock conflicts, 26 were bike/motor vehicle, and 24 of these were minor. In one of these serious conflicts, the motor vehicle turned right in front of the bicyclist after overtaking, and in the second a bicyclist turned or swerved across a lane of traffic. Twenty-three of the bike actions in the conflicts were slowing/stopping/swerving for traffic not influenced by the intersection. In two cases the bike turned or swerved across a traffic lane, and in one case the bike made an improper left turn. The most frequent motor vehicle actions were turning right after overtaking a bike, illegally parking in the BL, and having a driver or passenger enter or exit a parked or stopped vehicle.

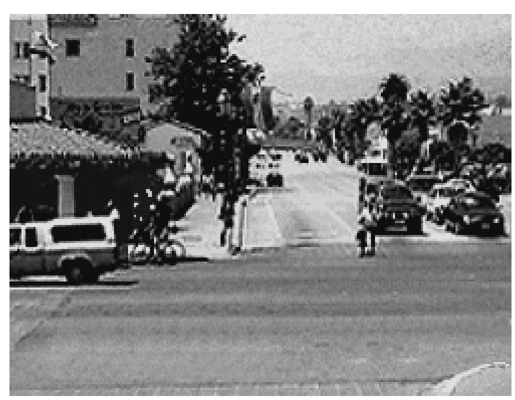
There were 10 bike/bike and 8 bike/pedestrian conflicts, and all were minor. The bike/bike conflicts typically ocurred as the bicyclists maneuvered toward their desired position at the intersection.

The most prevalent midblock conflict problem for this location pertained to the motor vehicle traffic turning right across the bike lane to enter the side street, or parking in the BL to drop off or pick up passengers. Conflicts also arose from the generally high volumes of bike and pedestrian traffic.

3. Intersection of Coast Village and Hot Springs - Santa Barbara, CA

- BL site with a short dashed stripe terminated prior to the intersection.
- 10 conflicts, 15.9 conflicts per 100 entering bicyclists.

Coast Village and Hot Springs is a three-legged, stop-sign-controlled intersection several miles away from the downtown area of Santa Barbara. The approaching 1.5-m BL on Coast Village has a short dashed stripe at the end of the marking but is terminated well back from the intersection because most bicyclists desire to shift to the left to go straight through the intersection. Coast Village has two lanes and an AADT of 8,300. The estimated driving speed is 64 km/h. At the intersection, the approaching lane becomes two lanes. Beginning at the centerline, there is a straight through lane and then a right turn lane. There is an



intersecting driveway from a parking area in the midblock area.

Of these 10 midblock conflicts, 9 were bike/motor vehicle, and all were minor. All of the bike actions in the conflicts were slowing/stopping/swerving for traffic not influenced by the intersection. Eight of the motor vehicle actions were failing to yield at

a driveway entrance/exit.

There was one bike/bike conflict, and it was minor.

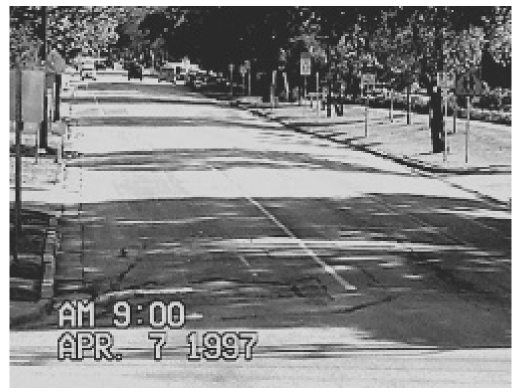
The most prevalent midblock conflict problem for this location pertained to the motor vehicle traffic entering or exiting the parking area driveway.

4. Intersection of SW 13th and SW 16th - Gainesville, FL

- BL site with stripe terminated just prior to the intersection.
- 19 conflicts, 15.6 conflicts per 100 entering bicyclists.

SW 13th and SW 16th is a four-legged, signal-controlled intersection south of the main campus of the University of Florida in Gainesville. The 2.1-m BL is on SW 13th Street, which has four lanes, with AADT of 23,500. The estimated driving speed is 64 km/h. At the intersection, the two approaching lanes become four lanes. Beginning at the centerline, there are two left turn lanes, then a through lane, and then a through-and-right lane. There is one intersecting street and two driveways in the midblock area.

Of these 19 midblock conflicts, 15 were bike/motor vehicle, and all were minor. In 15 conflicts the bicycle was making an advance crossover to the left.



Eleven of the bike actions in the 15 bike/motor vehicle conflicts were turning or swerving across a lane of traffic. The most frequent motor vehicle action was "none" (i.e., no action detected).

There were three bike/bike and one bike/pedestrian conflicts, and all were minor.

The most prevalent midblock conflict problem for this location pertained to bicyclists trying to make an advance crossover to the left prior to the busy intersection with its two left turn lanes for motor vehicle traffic.

5. Intersection of Speedway and 38th - Austin, TX

- BL site with stripe terminated prior to the intersection.
- 15 conflicts, 11.9 conflicts per 100 entering bicyclists.

Speedway and 38th is a four-legged, signal-controlled intersection north of the main campus of the University of Texas in Austin. The 1.5-m BL is on Speedway, which has two lanes, with AADT of 5,600.

The estimated driving speed is 53 km/h. At the intersection, the approaching lane splits into two through lanes. There is one intersecting street and one driveway in the midblock area. This street has many buses shuttling students to campus, and this was a major contributor to the conflicts.

Of these 15 midblock conflicts, 14 were bike/motor vehicle. Twelve were minor and the two others were coded as unsure as to whether serious or minor. In one of these "unsure" conflicts, the motor vehicle failed to yield at a driveway, and in the second a

driver or passenger was entering or exiting a parked or stopped vehicle. Eleven of the bike actions in the conflicts were slowing/stopping/ swerving for traffic not influenced by the intersection. The most frequent motor vehicle actions were related to interacting with parked or stopped vehicles (six cases where a driver or passenger was entering or exiting a vehicle, three cases where a vehicle was parked or stopped in the BL, and two cases where a vehicle was entering or exiting on-street parking).

The most prevalent midblock conflict problem for this location pertained to the interactions between bicycles and parked or stopped vehicles.

6. Intersection of Anacapa and Figueroa - Santa Barbara, CA

- WCL site with turn lanes added at the intersection.
- 5 conflicts, 9.4 conflicts per 100 entering bicyclists.

Anacapa and Figueroa is a four-legged, signal-controlled intersection in the business district of Santa Barbara. The 5.2-m WCL is on the right hand side of Anacapa, which is a one-way street with two lanes and AADT of 12,300. The estimated driving speed is 53 km/h. At the intersection, the two approaching lanes become three lanes. Beginning at the far left, there are two through lanes, and then a right turn lane. There is one intersecting street in the midblock area. Parking is allowed on the left side of Anacapa (90 minutes, from 9 a.m. to 6 p.m.).

Of these five midblock conflicts, all were bike/motor vehicle and minor in nature. All of the bike actions in the conflicts were slowing/stopping/swerving for traffic not influenced by the intersection. Two of the motor vehicle actions involved illegal parking in the WCL and another motor vehicle turned right in front of a cyclist after overtaking.

Although conflicts were few, there appeared to be a possible midblock problem with parked or stopped vehicles.

7. Intersection of E. 30th and Speedway - Austin, TX

- BL site with stripe carried to the intersection.
- 4 conflicts, 9.3 conflicts per 100 entering bicyclists.

E. 30th and Speedway is an intersection close to the University of Texas campus. The intersection has five legs and is stop sign controlled. The 1.6-m BL is on E. 30th, which is two lanes, with AADT of 6,300. The estimated driving speed is 53 km/h. There are no intersecting streets or driveways in the midblock area.

Of these four midblock conflicts, all were bike/motor vehicle and minor. All of the bike actions in the conflicts were slowing/stopping/swerving for traffic not influenced by the intersection. The most frequent motor vehicle actions were illegal parking in the BL.

The most prevalent midblock conflict problem for this location pertained to motor vehicles illegally parking in the BL.

8. Intersection of 22nd and Nueces - Austin, TX

- BL site with striping carried to the

intersection.

- 7 conflicts, 7.9 conflicts per 100 entering bicyclists.

22nd and Nueces is an intersection near the campus of the University of Texas. The intersection is four-legged and is stop sign controlled. The 1.5-m BL is on 22nd, which is two lanes, with AADT of 4,100. The estimated driving speed is 32 km/h. There is one intersecting driveway in the midblock area.

Of these seven midblock conflicts, all were bike/motor vehicle and minor in

nature. All of the bike actions in the conflicts were slowing/stopping/swerving for traffic not influenced by the intersection. The most frequent motor vehicle actions were illegal parking in the BL (five cases) and a driver or passenger entering/exiting a parked or stopped vehicle (one case).

The most prevalent midblock conflict problem for this location pertained to motor vehicles parking or stopping in the BL.

9. Intersection of Barton Springs and Dawson - Austin, TX

- WCL site with no turn lanes added at the intersection.
- 4 conflicts, 7.7 conflicts per 100 entering bicyclists.

Barton Springs and Dawson is a four-legged, signal-controlled intersection south of the central business district in Austin. The

4.1-m WCL is on Barton Springs, which is four lanes, with AADT of 22,000. A two-way left turn lane is present. The estimated driving speed is 56 km/h. There are no intersecting streets or driveways in the midblock area.

Of these four midblock conflicts, one was a minor bike/motor vehicle conflict, and the other three were minor bike/pedestrian conflicts. Because of the traffic volume, a good many bicyclists ride on the adjacent sidewalk along this street, which would lead to conflicts with pedestrians.

The most prevalent midblock conflict problem for this location pertained to bicyclists interacting with pedestrians on the sidewalk.

10. Intersection of Nueces and 22nd - Austin, TX

- BL site with striping carried to the intersection.
- 3 conflicts, 7.1 conflicts per 100 entering bicyclists.

Nueces and 22nd is an intersection near the campus of the University of Texas. The intersection is four-legged and is stop sign controlled. [Note: The other side of the intersection was also videotaped (see No. 8)

because of the frequency of bicycle riders.] The 1.2-m BL is on Nueces, which is a one-way street with two approach lanes and AADT of 3,500. The estimated driving speed is 40 km/h. There is one intersecting driveway in the midblock area.

Of these three midblock conflicts, two were bike/motor vehicle, and both were minor. One of the bike actions in the conflicts was for crowding vehicles in the travel lane and the other was "none." The motor vehicle actions were crowding the BL and being parked in the BL. There was one bike/pedestrian conflict, and the seriousness was minor.

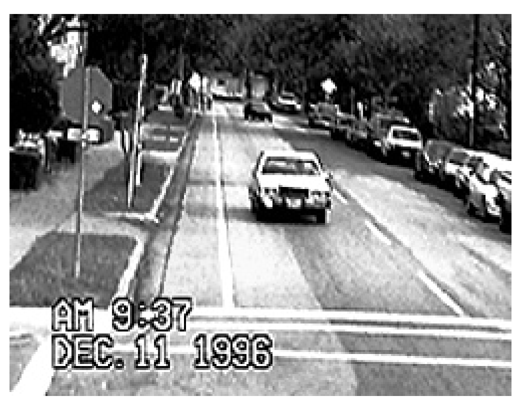
Although the conflict rate per entering bicyclist was high, there were not enough conflicts to identify a prevalent midblock conflict problem for this location.

Intersection conflicts

1. Intersection of Barton Springs and Dawson - Austin, TX

- WCL site with no turn lanes added at the intersection.
- 13 conflicts, 25.0 conflicts per 100 entering bicyclists.

Barton Springs and Dawson is a four-legged, signal-controlled intersection south of the central business district in Austin. The 4.1-m WCL is on Barton Springs, which has four lanes, with AADT of 22,000. A two-way left turn lane is present. The estimated driving speed is 56 km/h. There are no intersecting streets or driveways in the



intersection area.

Of these 13 intersection conflicts, 12 were bike/motor vehicle, and one of these was serious. In this conflict the bicyclist turned or swerved across a lane of traffic. For the bike/motor vehicle conflicts, seven of the bicycles were going straight through the intersection, three making left turns, and two making right turns. The bike actions in the conflicts were bicyclist failing to stop at the traffic signal (four conflicts), turning or swerving across a lane of traffic (two conflicts), passing slow or stopped vehicles on the right (two conflicts), and in one conflict the bicycle entered the roadway from the sidewalk. In four other conflicts the bike action was "none" (i.e., no action detected). The most frequent motor vehicle actions were slowing, stopping, or swerving due to intersection traffic (eight conflicts). In four conflicts the motor vehicle action was "none." There was one bike/pedestrian conflict, and the seriousness was minor.

This was quite a busy intersection at late-day peak hour, and instead of a "most prevalent conflict problem," it would appear that conflicts take place from a variety of bicyclist actions in maneuvering through this busy intersection.

2. Intersection of 43rd and Duval - Austin, TX

- WCL site with no turn lanes added at the intersection.
- 12 conflicts, 23.1 conflicts per 100 entering bicyclists.

43rd and Duval is an offset four-legged, stop- sign-controlled intersection in a neighbor- hood area north of the University of Texas campus in Austin. The 5.7-m WCL is on 43rd, which has two lanes, with AADT of 1,200. The estimated driving speed is 53 km/h. There is one intersecting driveway in the intersection area. The street is usually free of parked motor vehicles, but not always.

Of these 12 intersection conflicts, 10 were bike/motor vehicle, and all were minor. For the bike/motor vehicle conflicts, seven of the bicycles were making a left turn at the intersection, one a right turn, and two some other movement (e.g., pulling into a store area before getting through the intersection). Although most of the bike actions in the conflicts were slowing or stopping or swerv- ing for intersection traffic, in one conflict a bicyclist made an improper left turn and in another conflict a bicyclist failed to yield when changing lanes. The most frequent motor vehicle actions were entering or exiting on-street parking (five conflicts).

There were two bike/pedestrian con- flicts, and the seriousness was minor in both.

The most prevalent intersection conflict problem for this location pertained to bicycle interactions with parked vehicles.

3. Intersection of Speedway and 43rd - Austin, TX

- BL site with striping terminated prior to the intersection.
- 11 conflicts, 20.8 conflicts per 100 entering bicyclists.

Speedway and 43rd is a four-legged, stop-sign-controlled intersection in a busy bicycle corridor that is used by bicyclists to access the University of Texas campus in Austin. The 1.5-m BL is on Speedway, which is two lanes, with AADT of 5,600. The estimated driving speed is 56 km/h. There are two intersecting driveways in the intersection area that lead to a post office.

Of these 11 intersection conflicts, all were bike/motor vehicle, and none were serious. Ten of the bicycles were going straight through the intersection and one was making a left turn. Nine of the bike actions in the conflicts were bicyclist having to slow, stop, or swerve for traffic not influenced by the intersection. In two other conflicts the bike action was "none" (i.e., no action detected). The most frequent motor vehicle actions were related to parking: illegally parking in the BL (six conflicts), entering or exiting on-street parking (three conflicts), and a driver or passenger entering or exiting from a parked or stopped vehicle (one conflict). One other motor vehicle action involved turning right in front of the bicyclist after overtaking.

The most prevalent intersection conflict problem for this location pertained to bicycle interactions with parked or stopped vehicles near a busy post office.

4. Intersection of 34th and Guadalupe - Austin, TX

- WCL site with turn lanes added at the intersection.

- 7 conflicts, 17.1 conflicts per 100 entering bicyclists.

34th and Guadalupe is a four-legged, signal-controlled intersection west of the University of Texas campus in Austin. The 5.6-m WCL is on 34th, which has two lanes, with AADT of 8,950. At the intersection, the approaching lane becomes two lanes. Beginning at the centerline, there is a left turn lane, and then a through and right lane. The estimated driving speed is 48 km/h. There is one intersecting driveway in the intersection area. This is an intersection at which many bicyclists approach in the WCL but then turn right to head toward campus or the downtown area.

Of these seven intersection conflicts, six were bike/motor vehicle, and all were minor. For the bike/motor vehicle conflicts, four of the bicycles were going straight through the intersection, one making a right turn, and one was not coded. Five of the bike actions in the conflicts were having to slow, stop, or swerve for intersection traffic, and in one conflict a bicyclist was passing slow or stopped vehicles on the right. The most frequent motor vehicle actions were slowing, stopping, or swerving due to intersection traffic (three conflicts). In four conflicts the motor vehicle action was "none." In one conflict the motor vehicle was crowding the bicyclist in the WCL.

There was one bike/pedestrian conflict, and the seriousness was minor.

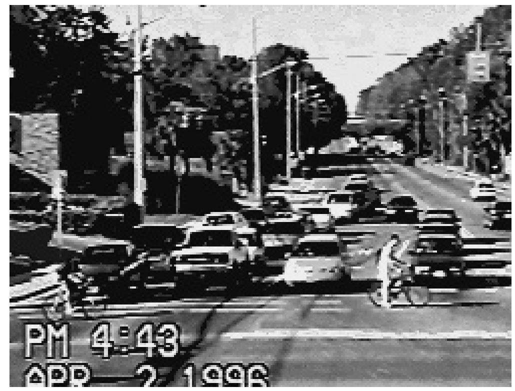
Instead of a "most prevalent conflict problem," it would appear that conflicts take place as a result of normal intersection maneuvering.

5. Intersection of SW 13th and SW 16th - Gainesville, FL

- BL site with stripe terminated just prior to the intersection.
- 20 conflicts, 16.4 conflicts per 100 entering bicyclists.

SW 13th and SW 16th is a four-legged, signal-controlled intersection south of the main campus of the University of Florida in Gainesville. The 2.1-m BL is on SW 13th Street, which has four lanes, with AADT of 23,500. The estimated driving speed is 64 km/h. At the intersection, the two approaching lanes become four lanes. Beginning at the centerline, there are two left turn lanes, then a through lane, and then a through-and-right lane. There are three intersecting driveways in the intersection area.

Of these 20 intersection conflicts, 18 were bike/motor vehicle, and one was serious. In this serious conflict the bicyclist turned or swerved across a lane of traffic and the motor vehicle used an improper lane. For the bike/motor vehicle conflicts, six of the bicycles were going straight through the intersection, five making left turns, and one a right turn. An "other" type of movement was taking place, such as cutting across the street to the left, in seven conflicts. The most frequent bike actions in the conflicts involved a bicycle turning or swerving across a lane of traffic (six conflicts), crowding vehicles in the travel lane (four conflicts), and having to slow, stop, or swerve for intersection traffic (four conflicts). In another conflict a bicyclist was riding in between slow or stopped vehicles. The most frequent motor vehicle actions were slowing, stopping, or swerving due to intersection traffic (10 conflicts). In seven conflicts the motor vehicle action was none. In one conflict the motor vehicle was using an improper lane (e.g., through from a right lane).



There was one bike/bike conflict, and the seriousness was minor.

The most prevalent intersection conflict problem for this location pertained to bicyclists trying to cross the street to the left prior to the busy intersection with its two left turn lanes for motor vehicle traffic. The speed and volume of traffic was such that it was rare that a bicyclist made a motor vehicle style left turn. In many cases an advance crossover to the left was made before reaching the intersection area.

6. Intersection of State and Cabrillo - Santa Barbara, CA

- BL site with dashed stripe leading to the intersection.
- 35 conflicts, 12.6 conflicts per 100 entering bicyclists.

State and Cabrillo is an intersection in the tourist area of Santa Barbara. The intersection is four-legged and signal controlled, but the leg opposite the approaching BL is an entrance to a popular wharf that contains shops and restaurants. The 1.2-m BL is on State Street, which has four lanes, with AADT of 9,000. The estimated driving speed is 53 km/h. At the intersection, the two approaching lanes become three lanes. Beginning at the centerline, there is a left turn lane, then a left-and-through lane, and then a right turn lane. There are two intersecting driveways in the intersection area.

Of these 35 intersection conflicts, 21 were bike/motor vehicle, and five of these were serious. In two of these serious

conflicts the motor vehicle failed to yield at a driveway, and in the other three the motor vehicle made an "other," or non-standard, movement. For the bike/motor vehicle conflicts, 14 of the bicycles were going straight through the intersection, 3 making left turns, and 2 making a right turn. Two were making some other kind of movement. Twelve of the bike actions in the conflicts were for slowing, stopping, or swerving for intersection traffic. In eight conflicts the bike actions were for slowing, stopping, or swerving for other traffic not influenced by the intersection. In one conflict a bicyclist used an improper lane, such as straight through from a right turn lane. The most frequent motor vehicle actions were "none" (seven conflicts), and making an "other" movement (seven conflicts). Other actions included failing to yield at a driveway (two conflicts), entering the BL to make a right turn but without yielding to the bicyclist (two conflicts), crowding (one conflict), and having a driver or passenger enter or exit a parked or stopped vehicle (one conflict).

There were 12 bike/bike and 2 bike/pedestrian conflicts, and all were minor except for one bike/bike conflict where a bicyclist was riding erratically.

The most prevalent intersection conflict problem for this location pertained to the weaving of bikes among themselves and with motor vehicles after the solid BL stripe ended. There was also a variety of maneuvering taking place at the intersection proper. Conflicts also arose from the generally high volumes of bike and pedestrian traffic.

7. Intersection of Speedway and 26th - Austin, TX

- WCL site with parking and with turn lanes added at the intersection.
- 21 conflicts, 10.8 conflicts per 100 entering bicyclists.

Speedway and 26th is a four-legged, signal-controlled intersection near the heart of the University of Texas campus in Austin. The 7.3-m WCL is on Speedway, which has two lanes, with AADT of 6,400. The estimated driving speed is 40 km/h. The approach

7.3-m WCL narrows to 4.1 m when angled parking and the addition of a left turn lane

begin about 85 m from the intersection. There are no intersecting streets or driveways in the intersection area. The angled parking area is usually filled with parked motor vehicles.

Of these 21 intersection conflicts, 17 were bike/motor vehicle, and 3 of these were serious. Two of these occurred when a bicyclist stopped at the controlled intersection but failed to yield. The third involved a motor vehicle turning right in front of a bicyclist after overtaking. For the bike/motor vehicle conflicts, 12 of the bicycles were going straight through, and 5 were making a left turn at the intersection. Although most of the bike actions in the conflicts were slowing, stopping, or swerving for intersection traffic (12 conflicts), in two conflicts the bicyclist stopped at the intersection but failed to yield, and in one conflict the bicyclist failed to stop at the traffic signal. The most frequent motor vehicle action was "none."

There was one bike/bike conflict and two bike/pedestrian conflicts, and the seriousness was minor in all three.

The most prevalent intersection conflict problem for this location pertained to the variety of maneuvering taking place at the intersection proper. Interactions between bicycles and parked motor vehicles were not a problem.

8. Intersection of Rio Grande and 24th - Austin, TX

- WCL site with turn lanes added at the intersection.
- 8 conflicts, 10.4 conflicts per 100 entering bicyclists.

Rio Grande and 24th is a four-legged, signal-controlled intersection near the heart of the University of Texas campus in Austin. The 4.5-m WCL is on Rio Grande, which is a one-way street with two lanes

and AADT of 6,600. The estimated driving speed is 40 km/h. The approach WCL narrows at the intersection with the addition of a left turn lane. There is one intersecting street and one driveway in the intersection area.

Of these eight intersection conflicts, seven were bike/motor vehicle, and none were serious. For the bike/motor vehicle conflicts, five of the bicycles were going straight through, and two were making another kind of maneuver near the intersection. The most frequent bike action in the conflicts was passing a slow moving or stopped vehicle on the right (five conflicts). Bicyclists would often make this maneuver to get up to the front of the intersection. The traffic signal has a long red phase, and often a bicyclist would stop and then proceed straight through if the cross street traffic allowed. The most frequent motor vehicle action was "none."

There was one bike/pedestrian conflict, and the seriousness was minor.

The most prevalent intersection conflict problem for this location pertained to bicyclists passing slow moving or stopped vehicles on the right.

9. Intersection of SW 13th and University - Gainesville, FL

- WCL site with full width carried through the intersection.
- 11 conflicts, 6.7 conflicts per 100

entering bicyclists.

SW 13th and University is a four-legged, signal-controlled intersection near the heart of the main campus of the University of Florida in Gainesville. The 4.4-m WCL is on SW 13th Street, which has four lanes, with AADT of 32,000. The estimated driving speed is 56 km/h. At the intersection, the two approaching lanes become three lanes as a left turn lane is added. However, the full width of the WCL is carried through the intersection. There is one intersecting street and two driveways in the intersection area.

Of these 11 intersection conflicts, 6 were bike/motor vehicle, and none were serious. For the bike/motor vehicle conflicts, four of the bicycles were going straight through the intersection, one making a right turn, and one “other” type of maneuver. The most frequent bike actions in the conflicts involved a bicycle passing slow moving or stopped vehicles on the right (two conflicts), and having to slow, stop, or swerve for traffic not influenced by the intersection (two conflicts). The most frequent motor vehicle action was “none.” In one conflict the motor vehicle turned right in front of the bicyclist after overtaking.

There was one bike/bike and three bike/pedestrian conflicts, and the seriousness was minor in all four.

The most prevalent intersection conflict problem for this location pertained to bicyclists passing motor vehicles on the right and interacting with pedestrians at the intersection. This is a busy intersection for motor vehicles, bikes, and pedestrians. Many bicyclists entering from the north will ride to the front of the intersection, move to the sidewalk, and then cross in the crosswalk area before turning right to head into campus.

10. Intersection of Rio Grande and 21st - Austin, TX

- BL site with striping carrried to the

intersection.

- 3 conflicts, 6.4 conflicts per 100 entering bicyclists.

Rio Grande and 21st is a four-legged, stop-sign-controlled intersection near the heart of the University of Texas campus in Austin. The 1.2-m BL is on Rio Grande, which is a one-way street with two lanes and AADT of 4,100. The estimated driving speed is 40 km/h. There is one intersecting street in the intersection area.

Of these three intersection conflicts, all were bike/motor vehicle. Two were coded as minor in nature and one as unsure. For the bike/motor vehicle conflicts, one of the bicycles was going straight through, one right, and one left. In two of the conflicts the bikes were having to slow, stop, or swerve for traffic not influenced by the intersection, and in the third conflict the bicyclist made an improper left turn. In two of the conflicts the motor vehicle action was a driver or passenger entering or exiting a parked or stopped car.

With only a few conflicts, no prevalent intersection conflict problem for this location could be identified with certainty, although parked motor vehicles again appear to be a problem.

Examination of Serious Conflicts

There were 17 serious conflicts coded from the videotape, 3 in the midblock (i.e., intersection approach) area and 14 at the intersection. These are described in the text that follows.

Serious midblock conflicts

Intersection of State and Cabrillo - BL Site
Santa Barbara, CA
Bicyclists were proceeding toward the intersection in the BL. A motorist overtook the bicyclists and then turned right into an intersecting street. The bicyclists had to swerve to avoid the turning vehicle.

Intersection of State and Cabrillo - BL Site

Santa Barbara, CA

The bicyclist was approaching the intersection in the BL. He switched to the adjacent traffic lane and then turned across a lane of traffic to cross the street to the left. The motorist applied brakes to avoid the bicyclist.

Intersection of State and Las Positas - WCL Site
Santa Barbara, CA
The bicyclist was approaching in a WCL. As traffic stopped for a motorist who was backing into a parking space, the bicyclist swerved quickly into the adjacent traffic lane and then back into the WCL.

Serious intersection conflicts

Intersection of SW13th and SW 16 TH - BL Site

Gainesville, FL

The bicyclist approached in the BL and then switched to the adjacent traffic lanes as he crossed the street to the left prior to the intersection. The motorist was trying to move to the left turn lane by going through the channelized area. The bicyclist made a rapid direction change.

Intersection of SW13th and SW8th - WCL Site
Gainesville, FL
The bicyclist was approaching the intersection in the WCL and was overtaken by a motorist who then started to turn right into a driveway. Both parties came to a full stop.

Intersection of State and Cabrillo - BL Site
Santa Barbara, CA
(Note: Two serious conflicts)

The bicyclist was approaching the intersection in the BL. The motorist was pulling out from a driveway and entered the BL. The bicyclist swerved to the left and came to a full stop. A second bicyclist (behind the motorcyclist) also had a serious conflict with this motorist.

Intersection of State and Cabrillo - BL Site
Santa Barbara, CA
(Note: Two serious conflicts)
Several bicyclists were approaching the intersection in the BL. The motorist passed the bicyclists and then turned right into a driveway. Two bicyclists had to change direction quickly to avoid being struck by the motorist.

Intersection of State and Cabrillo - BL Site

Santa Barbara, CA
The bicyclist was approaching the intersection in the BL. A passenger in a motor vehicle opened the right rear door, and the bicyclist had to swerve to the right to avoid striking the door.

Intersection of State and Las Positas - WCL Site
Santa Barbara, CA
A young male bicyclist was riding on the sidewalk approaching the intersection when a motorist pulled from a driveway into the sidewalk area. The bicyclist did a quick u-turn to avoid the vehicle.

Intersection of State and Ontare - WCL Site
Santa Barbara, CA
The motorist and bicyclist were approaching the intersection in the WCL. The motorist overtook the bicyclist and turned right into a driveway. The bicyclist had to quickly swing around the vehicle.

Intersection of Barton Springs and Dawson - WCL Site
Austin, TX
The bicyclist approached in the WCL and then crossed over to the two-way left turn lane. He then attempted to continue to cross to the left but had to brake and change direction quickly when he decided there was not time to cross in front of an oncoming motorist. The motorist had to brake.

Intersection of Guadalupe and 30th - WCL Site
Austin, TX
The bicyclist was going through the intersection in the WCL. He decided to shift to the left to avoid a section of rough

pavement. A following motorist had to shift to the left quickly to avoid the bicyclist.

Intersection of Speedway and 26th - WCL Site
Austin, TX
The bicyclist and motorist were near the intersection. From the inside lane, the motorist turned right across the outside lane. The bicyclist had to adjust quickly to avoid the vehicle.

Intersection of Speedway and 26th - WCL Site
Austin, TX
(Note: Two serious conflicts)
Two bicyclists had approached in the WCL. Both decided to disobey the traffic signal but had to quickly stop when a motorist approached from their left.

For the 17 serious conflicts described above, the primary causes were the following:

- Motorist turned right soon after overtaking bicyclist - six conflicts
- Motorist pulling from driveway to street - three conflicts
- Motorist parking maneuver/ passenger exiting stopped vehicle - two conflicts
- Bicyclist turned or swerved across a lane of traffic - three conflicts
- Bicyclist disobeyed traffic signal - two conflicts
- Bicyclist shifted to path of motorist to avoid rough pavement - one conflict

Comparisons with Crash Data

In addition to videotaping the behavior of bicyclists at WCL and BL sites,two years (1994 and 1995) of recent police-reported bicycle-motor vehicle crash data were obtained for each of the three participating cities (Gainesville, Austin, and Santa Barbara). Actual hard copies of the police reports were reviewed by project staff, and the 1995 crashes were "typed" following the methodology originally developed by NHTSA[1] and being modified in partnership with FHWA for computer application. The computer software will be known as PBCAT (Pedestrian and Bicycle Crash Analysis Tool). Although the crash typing was done primarily to identify and examine interesting parallels to the videotape data, the typing also provided a way to generate some useful feedback to the participating cities. This section highlights the results of these crash and videotape comparisons.

At the outset, it should be emphasized that, whereas the crash data reflect events occurring throughout a city, the videotape data are limited to 16 intersections within that city with very specific, predefined characteristics (e.g., a BL or WCL on a low-speed roadway). Thus, the videotape data cannot be regarded as "exposure data" for the crash events. On the other hand, the 16 selected sites in each of the cities do represent locations with high levels of bicycle traffic, so that any patterns of riding behavior at these sites might reasonably be expected to extend to the city as a whole, and be reflected in their crash data.

Table 22 summarizes the primary crash types identified for each city. During 1995, there were 158 reported bicycle-motor vehicle crashes in Gainesville, 173 in Austin, and 77 in Santa Barbara. Overall, the most frequently occurring crash types were on average:

Average	Percent
Motorist Drive Out at Stop Sign	16.4
Motorist Drive Out at Midblock	10.9
Bicyclist Ride Out at Intersection	10.2

However, there are distinctive crash types that stand out in each city. In Santa Barbara, for example, one of the two most frequently occurring crash types was the Bicyclist Striking a Parked Vehicle: 16 percent of all reported crashes. A typical situation was the cyclist riding alongside a row of parked vehicles and running into an opening car door. Only 3 percent of Austin's crashes were parked vehicle-related, and none of the crashes in Gainesville. From the videotape data, 41 percent of the Santa Barbara bicyclists were recorded as riding next to parked vehicles (e.g., a combined BL and parking facility), 21 percent of the Austin bicyclists, and none of the Gainesville bicyclists. Thus, the availability of bicycle facilities with on-street parking appears to be directly related to the higher proportion of crash types involving parked vehicles.

In Gainesville, the most frequently occurring crash type was Motorist Drive Out at Stop Sign — nearly a fourth of its reported crashes. In three out of four of these crashes, the bicyclist was traveling on the sidewalk, facing traffic (i.e., approaching from the motorist's right). The videotape data also exhibited a high

[1]For more complete background on bicycle-motor vehicle crash typing, see Hunter, Stutts, Pein, and Cox (1996).

level of sidewalk and wrong way riding in Gainesville. Seventeen percent of the Gainesville bicyclists captured on videotape were observed approaching the

Table 22. Most frequent occurring crash types rank ordered in each of the three study sites, based on 1995 police-reported crash data.

Rank	**Gainesville** (N=158)	**Austin** (N=173)	**Santa Barbara** (N=77)	**Overall ***
1	Drive Out at Stop Sign (24.7%)	Drive Out at Stop Sign (15.6%)	Bicyclist Strikes Parked Vehicle (15.6%)	Drive Out at Stop Sign (16.4%)
2	Right Turn On Red (14.6%)	Ride Out at Intersection (13.9)	Motorist Right Turn (15.6%)	Drive Out at Midblock (10.9%)
3	Drive Out at Midblock (12.7%)	Ride Out at Midblock (11.6%)	Drive Out at Midblock (13.0%)	Ride Out at Intersection (10.2)
4	Ride Out at Intersection (10.8%)	Motorist Left Turn- Facing Bicyclist (8.7%)	Drive Out at Stop Sign (9.1%)	Motorist Right Turn (8.3)
5	Motorist Left Turn- Facing Bicyclist (7.0%)	Drive Out at Midblock (6.9%)	Motorist Overtaking (7.8%)	Right Turn on Red (7.6)
6	Motorist Right Turn (6.3%)	Right Turn On Red (6.9%)	Ride Out at Intersection (6.5%)	On-Street Parking Related (7.1)
7	Ride Out at Midblock (5.1%)	Bicyclist Left Turn In Front Of Motorist (5.8%)	Motorist Left Turn- Facing Bicyclist (5.2%)	Motorist Left Turn - Facing Bicyclist (6.9)
8	Drive Through (4.4%)	Assault (4.0%)	Bicyclist Lost Control (5.2%)	Ride Out at Midblock (6.0)
9		Motorist Left Turn- Bicyclist Same Direction (4.0%)	Drive Out From On-Street Parking (3.9%)	Motorist Overtaking (3.9)
10		Motorist Overtaking (4.0%)		
	85.4% of Total	81.5% of Total	77.9% of Total	77.3% of Total

* Percentage based on an average of the percents for each city (i.e., not weighted by sample size).

targeted intersections on the sidewalk; this compares with less than 3 percent of the Austin bicyclists and less than 2 percent of the Santa Barbara bicyclists. In addition, 9 percent of Gainesville bicyclists were observed traveling the "wrong" direction (i.e., facing oncoming motor vehicle traffic) on a sidewalk, compared with only 1 percent of both the Austin and Santa Barbara bicyclists. Wrong-way sidewalk riding was also a factor in 87 percent of Gainesville's Right Turn on Red crashes, and 75 percent of their Drive Out at Midblock crashes.

Sidewalk riding, and in particular wrong-way sidewalk riding, was clearly a contributing factor in Gainesville's crashes.

Ride-out at Intersection crashes occur when the bicyclist runs a stop sign or traffic signal, or fails to yield at an uncontrolled intersection, and strikes a vehicle approaching on a crossing path. This crash type occurred most frequently in Austin (14 percent), followed by Gainesville (11 percent) and then Santa Barbara (6 percent). The percentages of bicyclists observed on the videotapes disobeying signals or stop signs (mostly the latter) were:

	% Disobeying Signal	% Disobeying Stop Sign
Gainesville	12	38
Austin	8	20
Santa Barbara	5	17

The overall lower rates for Santa Barbara parallel the crash results. Gainesville had a considerably higher rate of "ride out" behavior than Austin, however, which is not reflected in the crash data. Part of this may be due to the locations selected for the videotaping and the nature of the traffic flow at these locations. In particular, there were several sites in Gainesville where many bicyclists ran stop signs, but where motor vehicles had adapted to this behavior and crash risk was minimal.

Other riding behaviors observed among the videotaped Gainesville bicyclists were displayed in the crash data. For example, there was a much higher percentage of incorrect left turns observed among the Gainesville riders — 11 percent of the riders made improper motor vehicle style turns, and nearly 25 percent made a left turn from the bike lane (most of these from a single site, a t-intersection where almost all of the bike and motor vehicle traffic made a left turn). This compares with 5 percent or fewer of the Austin and Santa Barbara bicyclists noted for such movements. Only one of Gainesville's reported crashes, however, involved a left-turning bicyclist. Gainesville cyclists were also more likely to employ a non-standard right turn method (17 percent of right turn movements, compared with 11 percent for both Austin and Santa Barbara). But although Gainesville had more right-turn crashes than the other sites, overall numbers were low (three right-turning crashes for Gainesville, one in Austin, and none in Santa Barbara).

The one left-turning behavior observed in the videotape data that might have a parallel in the crash data is a higher percentage of "advance crossover" intersection maneuvers for the Austin bicyclists (11 percent of all left turns, compared with 3 percent in both Gainesville and Santa Barbara). Nearly 6 percent of the crashes reported for Austin were Bicyclist Left Turn in Front of Motorist. None of these type crashes were reported for Gainesville or Santa Barbara.

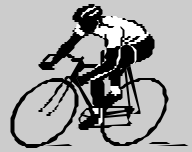
Clearly, one cannot expect behaviors observed on one or two occasions at a relatively small subset of intersections to mimic precisely overall riding behavior within a city. Nevertheless, certain conditions — on-street parking, sidewalk riding, wrong-way riding, even heavy traffic that makes turning maneuvers difficult — may persist and may indeed have counterparts in the crash data. The comparisons drawn in this section would likely have been stronger if young children had been excluded from the crash data. Children under age 15 were involved in 27 percent of the Austin crashes, 15 percent of the Gainesville crashes, and 10 percent of the Santa Barbara crashes. In contrast, less than

1 percent of the videotaped bicyclists were categorized as children. Another difference in the two samples is that all of the videotaping was done during the daytime, whereas the percentage of crashes reported under daylight conditions in the three cities varied from 81 to 89 percent. In each city, however, certain riding conditions prevail, and these appear to have been reflected in both the videotape and the crash data.

Chapter

4

Discussion



This comparative analysis was based on videotapes of almost 4,600 bicyclists in three U.S. cities approaching and then riding through intersections for which the associated bicycle facility was either a BL or WCL. In two of the three cities, the vast majority of bicyclists were traveling to or from college campuses, and the intersections selected were generally in bicycle commuting corridors. The intent was to videotape bicyclists who regularly ride in traffic. The result was a group of sites with varying "real-world" characteristics such as different BL striping techniques (e.g., using a solid or dashed BL stripe all the way to the intersection), presence of parking (e.g., a combination BL and parking lane), and provision of turn lanes at intersections that sometimes narrow the nominal width of the BL or WCL at the intersection proper. What follows is a brief summary of the main operational and safety (conflict) results and some further elaboration of key issues.

Summary of Main Results

Bicyclist characteristics

- The overwhelming majority of videotaped bicyclists were between the ages of 16 and 64. Slightly more than three-fourths were male.
- Overall, 5.6 percent of the bicyclists were riding the wrong way (i.e., facing traffic). This included 1.3 percent in the road and 4.3 percent on sidewalks. However, wrong-way riding was much more prevalent on the sidewalk at WCL sites (7.0 percent) compared with BL sites (2.3 percent). Eliminating sidewalk riding from the comparison, however, still resulted in significantly more wrong-way riding associated with WCL sites (1.7 percent) than BL sites (1.0 percent).
- A bicyclist experience oral survey was administered to bicyclists proceeding through the project sites on days when videotaping was not being done. There were no statistically significant differences in the age, gender, and helmet use of bicyclists by type of facility. Higher proportions of Whites and Blacks rode in WCL situations and higher proportions of Asians and Hispanics in BL situations, and the differences were significant.
- Bicyclists surveyed at WCL sites tended to ride more days per week, but the miles per week for bicyclists at BL versus WCL sites were equivalent. Overall, about one-third of the riders at both BL and WCL sites considered themselves to be experienced bicyclists.
- When bicyclists were surveyed, their riding location (i.e., in the street or on the sidewalk) when approaching the survey station was recorded. Surveyed bicyclists showed the same tendency as the videotaped bicyclists in that sidewalk riding was more associated with WCL sites.

Midblock movements

- In the midblock or intersection approach area (between 90 and 150 m from the intersection), significantly more motor vehicles passing bicycles on the left encroached into the adjacent traffic lane from WCL situations (17 percent) compared with BL situations (7 percent). This is in agreement with results from a recent Florida DOT study (Harkey and Stewart, 1997). However, encroachments into the adjacent traffic lane very rarely resulted in a conflict with another motor vehicle.

Statistical modeling of spacing between bicycles and motor vehicles

Least squares regression analysis was used to develop models to investigate how spacing between bicycles and motor vehicles differed, on average, as a function of various roadway and traffic characteristics. Main results were:

- When bicycles were *not* being passed by motor vehicles, for BL widths equal to or less than 1.6 m, the average bicycle distance from the curb (or gutter pan seam, when present) was less than for WCLs having the same traffic volume. For BLs greater than 1.6 m wide, however, the average bicycle distance from the curb was greater than for WCLs having the same traffic volume.
- When bicycles *were* being passed by motor vehicles, results were similar to the above. Bicycles tended to be positioned about 0.3 m closer to the curb when being passed than when not. The relevant model again predicted distances from bike to curb to be smaller for BLs less than 1.5 m and larger for BLs equal to or wider than 1.5 m than for WCLs with similar traffic volume. Distance from the bicycle to the passing motor vehicle was developed from another model and was primarily a function of the total width available, along with slight driving speed and traffic volume effects. Total width was defined as the BL width plus the width of the adjacent traffic lane, or simply the width of the WCL when no BL was present. Thus, for comparable speed and traffic conditions, the distance from the bicycle to the passing motor vehicle was a direct function of total width, whether the primary bicycle facility was a BL or WCL.
- On average, bicyclists rode about the same distance from *parked vehicles* at BL sites with parking as they did to the curb (or gutter pan seam) when parked vehicles were not present.

Intersection movements

- The intersection was defined as starting 90 m upstream from the stop bar and included the intersection proper. Proportionally more bicyclists approached the intersection on a sidewalk when the facility was a WCL (15 percent) than a BL (3 percent).
- Overall, 92 percent of bicyclists obeyed the traffic signals that were present, and there were no differences by facility type. When a signal was disobeyed, 16 percent of the actions were considered somewhat unsafe and 2 percent definitely unsafe. There were no differences by facility type.
- Overall, 75 percent of bicyclists obeyed existing stop signs. Proportionally more bicyclists obeyed stop signs at BL sites (81 percent) than at WCL sites (55 percent). When a stop sign was disobeyed, 13 percent were considered somewhat unsafe and 2 percent definitely unsafe. The proportion of bicyclists with both somewhat unsafe (19 versus 5 percent) and definitely unsafe (3 versus 0 percent) movements was higher at BL sites. The differences between BL and WCL sites were significant when the somewhat unsafe and definitely unsafe categories were combined.
- Seventy-two percent of the bicyclists went straight through the intersection, with another 15 percent turning left and 13 percent turning right. There were no differences by facility type. Nine percent of the bicyclists tended to shy to the right (i.e., move to the right and away from traffic) as they went straight through the intersection (11 percent in BLs and 7 percent in WCLs), and this difference was significant.
- Left turns presented a problem for bicyclists and were made in a variety of ways. Overall, 44 percent made left turns like a motor vehicle with *proper* lane destination positioning (41 percent from BL

sites and 48 percent from WCL sites). On the other hand, 14 percent of bicyclists at WCL sites made motor vehicle style left turns with *improper* lane destination positioning compared with 3 percent from BL sites. There were proportionally more pedestrian style left turns from WCL sites (24 percent versus 12 percent from BL sites). Both findings may reflect the generally higher traffic volumes and speeds and greater number of lanes at WCL sites.

- Right turns for bicyclists were an easier maneuver, with only 13 percent made in a non-standard fashion (e.g., from a BL or WCL to a wrong-way position on the cross street). Nineteen percent of the right turns made at WCL sites were non-standard versus 10 percent of right turns at BL sites, and the differences were significant.

Midblock conflicts

- Of the 188 midblock conflicts, 71 percent were bicycle/motor vehicle, 10 percent bicycle/bicycle, and 19 percent bicycle/pedestrian. Almost all of the bike/bike conflicts occurred in BLs. Compared with BLs, bicyclists in WCLs experienced more bike/pedestrian conflicts (30 percent versus 16 percent, and reflective of the increased sidewalk riding in WCL situations) and less bike/bike conflicts. The differences by facility type were statistically significant.
- There were no differences in the bicycle or motor vehicle avoidance response scales by facility type. The scales ranged from no change in riding or driving up to collision or near crash.
- Overall, 98 percent of the midblock conflicts were coded as minor, and there were no differences by facility type.
- Bicycle actions more associated with BLs in these midblock conflicts included the bicycle having to slow, stop, or swerve for traffic not influenced by the intersection; the bicycle turning or swerving across a lane of traffic; encounters with other bikes; and "other" bike actions (such as an improper left turn). The bicycle action more associated with WCLs in these midblock conflicts was encounters with pedestrians.
- Motor vehicle actions more associated with BLs in these midblock conflicts included illegal parking in the BL and entering/exiting on-street parking or a driver or passenger entering/exiting a parked or stopped vehicle. Motor vehicle actions more associated with WCL conflicts included turning right in front of a bicyclist after overtaking and "other" actions such as failing to yield, improper right turns, and crowding bikes.

Intersection conflicts

- Of the 198 intersection conflicts, 79 percent were bike/motor vehicle, 10 percent bike/bike, and 10 percent bike/pedestrian. The differences in the BL/WCL distributions were statistically significant. There were proportionally more bike/bike conflicts in BLs (15 percent) and less in WCLs (4 percent). Conversely, there were proportionally more bike/pedestrian conflicts in WCLs (17 percent, and again reflective of sidewalk riding) and less in BLs (6 percent).
- The position of the motor vehicle with respect to the bicycle in the intersection conflicts was 66 percent in the same direction, 6 percent in the opposing direction, 5 percent approaching from the left, 15 percent approaching from the right, and 7 percent approaching from some other position. There were no differences by facility type.
- There were no differences in the bicycle or motor vehicle avoidance response scales by facility type.

- Overall, 93 percent of the intersection conflicts were coded as minor, and there were no differences by facility type.
- Bicycle actions more associated with BLs in these intersection conflicts included the bicycle having to slow/stop/swerve for intersection traffic, the bicycle having to slow/stop/swerve for traffic not influenced by the intersection, and the bicycle turning or swerving across a lane of traffic. Bicycle actions more associated with WCLs included passing slow moving or stopped vehicles on the right, encounters with pedestrians, and "other" actions such as improper left turns and merging onto the road from a sidewalk.
- Motor vehicle actions more associated with BLs included illegal parking in the BL and "other" actions such as a driver or passenger entering/exiting a parked or stopped vehicle and crowding the BL. Motor vehicle actions more associated with WCLs included having to slow/stop/swerve for intersection traffic and turning right in front of a bicyclist after overtaking.

Statistical modeling of conflict data

- Raw frequency conflict rates per entering bicyclist were slightly higher at BL sites than WCL sites when midblock and intersection conflict data were combined (6.7 versus 5.1 bike motor vehicle conflicts per 100 entering bicyclists).
- The rate of *midblock* bike/motor vehicle conflicts associated with BLs was considerably higher than the rate for WCLs, although the rates were small. Generalized linear models fitted to the data showed that both the presence of a BL and the BL width, along with traffic volume and the presence of driveways, were significant variables in the midblock conflict rate models. The practical effect of such models was that the midblock bike/motor vehicle conflict rate was higher at sites with BLs less than 2.5 m wide than at WCL sites. However, a closer examination of the data revealed that the higher midblock BL conflict rates were attributable to only a few sites. The midblock conflicts at the 10 highest rate sites were thus examined clinically.
- An initial model fitted to the *intersection* conflicts showed no differences in the conflict rate by type of bicycle facility, but higher conflict rates for left turn movements. A subsequent model was developed that included different intersection types based on the type of BL striping (e.g., solid stripe to the intersection, dashed stripe to the intersection) and whether the typical WCL cross section was maintained through the intersection (or narrowed due to the provision of turn lanes). This model showed *lower* conflict rates for straight through and right turning bicycles where the BL stripe continued all the way to the intersection and the WCL was not narrowed at the intersection.

Clinical examination of high conflict rate sites

- The 10 highest conflict rate sites for both the midblock and intersection areas were examined clinically to determine if any typical conflict patterns existed. In the *midblock* area, there were seven BL and three WCL sites. The predominant motor vehicle actions in the midblock conflicts pertained to motor vehicles entering or exiting on-street parking (there were several sites where parking was part of the facility), parking or stopping in the bicycle facilities to let a passenger enter or exit the vehicle, and pulling across the BL or WCL into an intersecting street or driveway. The predominant bicycle actions were turning or swerving across a lane of traffic (usually to avoid making a left turn at the intersection ahead) and interacting with pedestrians when riding on the sidewalk. If "fault" in the conflicts had been assigned, the large majority of the fault would have been due to motor vehicle actions.

- In the *intersection* area, there were four BL and six WCL sites. The predominant motor vehicle actions again pertained to entering or exiting on-street parking and parking or stopping in the bicycle facility to let a passenger enter or exit the vehicle. The predominant bicycle actions were turning or swerving across a lane of traffic, passing slow or stopped motor vehicles on the right, and interacting with pedestrians. Some of the conflicts resulted simply from the typical maneuvering that might occur when bicycles and motor vehicles position themselves to make turns at intersections. If "fault" in the conflicts had been assigned, the majority would have been due to bicycle actions.
- Identifiable situations leading to conflicts from this clinical analysis were presence of parked motor vehicles (either entering/exiting legal parking or illegal parking/stopping) in the BL or WCL, presence of driveways or intersecting streets, and provision of turn lanes at intersections that typically (but not always) resulted in a narrowing of the BL or WCL at the intersection proper (normally in the last 30 to 50 m before the stop bar). Except for combined BL and parking facilities, these situations did not appear to be related to whether a BL or WCL was present. In other words, the conflicts that resulted were site-specific and likely would have occurred whether a BL or WCL was present.

Clinical examination of serious conflicts

- Seventeen conflicts were coded as serious, 10 at WCL and 7 at BL sites. If "fault" had been assigned, 11 would have been the fault of the motorist and 6 the fault of the bicyclist. The motorist turned right soon after overtaking the bicyclist in six of the conflicts, pulled from a driveway to the street in three conflicts, and was involved in a parking situation in the other two cases. The bicyclist turned or swerved across a lane of traffic in three conflicts, disobeyed a traffic signal in two cases, and shifted in front of a motor vehicle in the process of avoiding rough pavement in the other. Examining these situations clinically, there appeared to be no differences between BL and WCL serious conflicts.

Comparisons with crash data

- One year (1995) of police-reported crash data was "typed" using the NHTSA methodology for all three of the project communities. There were parallels to the videotape data.
- In Santa Barbara, one of the two most frequently occurring crash types was the bicyclist striking a parked vehicle. Santa Barbara had a number of individual intersections where parking was part of the bike facility, and overall 41 percent of the bicyclists were recorded as riding next to parked vehicles, as compared with 21 percent of the Austin bicyclists and none of the Gainesville bicyclists.
- In Gainesville, the most frequently occurring crash type was Motorist Drive Out at Stop Sign. In three out of four of these crashes, the bicyclist was riding the wrong way (facing traffic) on the sidewalk. Seventeen percent of the Gainesville bicyclists were observed approaching the targeted intersections on the sidewalk, as compared with less than 3 percent of the Austin bicyclists and less than 2 percent of the Santa Barbara bicyclists. In addition, 9 percent of the Gainesville bicyclists were observed riding the wrong direction on a sidewalk, compared with 1 percent of both the Austin and Santa Barbara bicyclists. Wrong-way sidewalk riding was also a factor in 87 percent of Gainesville's Right

Turn on Red crashes, and 75 percent of its Drive Out at Midblock crashes.

- In Austin, 11 percent of the bicyclists made "advance crossovers" to the left prior to the intersection, as compared with 3 percent in both Gainesville and Santa Barbara. Nearly 6 percent of the crashes reported for Austin were Bicyclist Left Turn in Front of Motorist. None of these types of crashes were reported for Gainesville or Santa Barbara.

Further Comment

Level of experience

Many in the bicycling community have assumed that more experienced bicyclists tend to use WCLs and that lesser experienced bicyclists use BLs. This issue was explored in this project by use of an oral questionnaire, where each surveyed bicyclist was asked to read or listen to a statement being read to them about their experience or comfort level on certain types of facilities (see chapter 2 for details). Overall results showed that 34 percent of the bicyclists considered themselves to be experienced, and there were no differences by type of facility.

Wrong-way riding

Wrong-way riding, or riding facing traffic, was present for approximately 6 percent of the videotaped bicyclists. There seems to be a prevailing feeling that this practice is more widespread in BLs, but in this study a higher proportion of the wrong-way riding tended to occur at WCL sites, whether in the roadway or on the sidewalk. Proportionally more of the WCL wrong-way riding took place on the sidewalk; however, eliminating sidewalk riding from the tabulation still showed significantly more wrong-way riding in the street associated with WCL sites. This may be related to the fact that WCLs are often associated with higher volume roadways and that maneuvering through intersections on these roadways can be a complex task. Thus, the bicyclist may choose what seems to be a safer route by riding the wrong way on an adjacent sidewalk or in the street. It may not be safer in actuality, as wrong-way riding either in the street or on a sidewalk is a frequent factor in bicycle-motor vehicle crashes (See Hunter, Stutts, Pein, and Cox, 1996).

Turning and other maneuvers at intersections

Besides the sidewalk riding mentioned above, complexity of traffic at the WCL intersections in this study may also be related to the operational findings that more incorrect left-turn destination positioning and pedestrian-style left turns were associated with WCL intersections. In addition, WCL sites had proportionally more non-standard right turns than BL sites. Left turns presented problems at BL sites as well. An intersection conflict model showed higher conflict rates for straight and right turning bicycles where the bike lane was terminated prior to the intersection, dashed to the intersection, or the nominal width of the BL or WCL was narrowed due to the provision of turn lanes. A prevalent conflict in these situations, whether at a BL or WCL site, was for a motor vehicle to pass a bicyclist and then turn right soon after the overtaking maneuver was made. Experienced bicyclists can prevent some of these conflicts by taking control of the lane with their positioning, particularly within the intersection, so that the motor vehicle cannot pass. More bicyclists need training related both to turning maneuvers at intersections and to safely negotiating these areas if merely going straight through.

Intersections continue to account for about half of all bicycle-motor vehicle crashes (Hunter, Stutts, Pein, and Cox, 1996).

Conflicts

There were nearly 400 midblock and intersection conflicts noted, but the vast majority were minor in nature. There was no difference in the severity level of the conflicts for BL versus WCL sites as measured by bicycle or motor vehicle response scales to conflicts. Bike/bike conflicts were more associated with BLs, while bike/pedestrian conflicts were more associated with WCLs. Unadjusted conflict rates showed BL sites to have slightly higher rates per entering bicyclist than WCL sites.

Many midblock and intersection conflict models were attempted to identify significant variables related to the occurrence of conflicts. A *midblock* conflict model showed that presence and width of a BL were significantly related to conflicts, along with traffic volume and presence of driveways. Conflicts increased with traffic volume, number of driveways, presence of a BL, and narrower BLs. The interpretation question was whether the higher conflict rates were really attributable to these variables, particularly narrower BLs, or to site-specific characteristics for a few locations. Further analysis showed that a few sites with narrower BLs and high conflict rates tended to greatly affect the results.

As another example of the interpretation problem, the same data described above were modeled by eliminating two atypical WCL sites for which vehicles parking on the street during the videotaping reduced the effective space available to that of a regular traffic lane, instead of a WCL. One of these sites had a high traffic volume, two driveways, and a high conflict rate. The other had low traffic volume, one driveway, and a lower conflict rate. Eliminating these sites and refitting the model to the data led to the *elimination* of both the traffic volume and driveway factors. However, both factors seem intuitively related to higher conflict rates.

The difficulty of statistically interpreting outcomes that seemed so dependent on site-specific characteristics led to clinical analysis of higher conflict rate sites, both at midblock and intersection locations. Results of this clinical analysis showed several factors to be consistently related to the occurrence of the conflicts: (1) presence of parked motor vehicles (either entering/exiting legal parking or illegal parking/stopping) in the BL or WCL, (2) presence of driveways or intersecting streets, and (3) provision of additional (usually turn) lanes at intersections that typically (but not always) resulted in a narrowing of the BL or WCL. Fortunately, these are factors for which some countermeasures are available.

Recommended Countermeasures for Certain High Conflict Rate Problems

Parked motor vehicles

Motor vehicle parking conditions vary widely, and there can be large differences between all day parking with low turnover and high turnover parking that typically serves retail stores. High turnover from on-street parking was one of the situations that led to conflicts with bicycles in this study. The other problem situation was illegal parking or stopping in the bicycle facility. Many communities in the United States allow motor vehicles to park in bicycle facilities, particularly BLs, during some portions of the day, generally when bicycle

Figure 17. Standard no parking signs for bike lanes.
Source: Oregon Bicycle and Pedestrian Plan, 1995

traffic is low. In other words, there is no bicycle facility when motor vehicles are allowed to park. This practice can only function effectively if police enforcement keeps the motor vehicles out of the facility during the time parking is prohibited. However, this kind of enforcement is

Figure 18. Double striped BL with parking.

difficult to maintain, and violations of these parking provisions are apparent even in bicycle-friendly communities. Eliminating parking altogether in the bicycle facility is a much stronger statement. If bicycling is to be a truly integrated and useful form of transportation, then bicyclists should have facilities available throughout the day.

In like fashion, motor vehicles do not hesitate to pull into BLs to allow passengers to enter or exit. In areas of busy bicycle traffic, this can lead to many conflicts. At the least, standard “no parking in bike lane” signs

Figure 19. Combination BL with parking T’s.

(figure 17) should be used liberally. More often than not, however, this is an enforcement issue.

Besides enforcement, good design policy can help to eliminate some of the conflicts. If motor vehicle parking is an intended part of a BL, then a double-striped 1.5-m BL that positions the right most BL stripe at least 0.9 m from parked vehicles is recommended to provide the best channelization of bicyclists (figure 18). At least 2.4 m should be allowed for parking. When available right-of-way does not allow the double striped BL described above, then a combination lane, intended for both motor vehicle parking and bicycle use, is an alternative. Such a lane should be at least 3.7 m wide, with 4.3 m being preferable, and contain parking T’s (sometimes referred to as tick marks) to denote the parking spaces (figure 19).

Bicyclist education about correct position when riding on streets with on-street parking is also highly recommended. Bicyclists should be at least 0.9 m from parked vehicles, and riding should be in a straight line. Such recommendations can be easily highlighted on a community bicycle map.

Driveways and intersecting streets

Driveways and intersecting streets in either the midblock or intersection area can lead to bike/motor vehicle conflicts. Driveways or alleys in commercial areas are normally the culprits because more motor vehicle traffic is present. Sometimes the problem is the motorist driving out of a driveway or alley and failing to stop before crossing a sidewalk or an implied sidewalk area that has bicycle travel (figure 20). Clear sight lines should be provided for the motorist if possible. If the sidewalk ends at the driveway cut, a crosswalk could be painted (with optional advance stop bar), or the sidewalk could be extended across the driveway cut. A "WATCH FOR BICYCLISTS" sign could also be installed.

Treatments can also be developed for the bicyclist riding on the sidewalk. First and foremost, education should be provided about the dangers of sidewalk riding, and especially wrong-way riding that places the bicyclist out of the normal viewing pattern for a motorist exiting from a commercial driveway or alley. Bicyclists should also be cautioned to ride slowly in these areas that are primarily designed for walking speeds. Painting "USE CAUTION" on the sidewalk at hazardous driveways is also recommended.

Most of the problems noted at the high conflict rate sites in this project involved bicyclists riding in the street, however, and not on the sidewalk. From anecdotal observation, it would seem as though motorists are not hesitant to use a BL as a buffer when they exit from a commercial driveway or alley into the street. A remedy is to provide a stop bar for the motorist prior to the BL. "WATCH FOR BICYCLISTS" or "YIELD TO APPROACHING BICYCLISTS" signs might be helpful in this situation. Dashing the BL stripe at busy driveways is also recommended, not only to alert a motorist that a bicyclist may be approaching because of the presence of the BL but also to alert a bicyclist that a motorist may be emerging from the driveway adjacent to the dashed stripe.

Equally important is the problem of motorist overtaking where a right turn is made into the driveway soon after the overtaking is completed. Bicyclist education about the danger of driveways is warranted, with the message focusing not only on motorist-drive-out but also on motorist-overtaking situations. Motorist education relating to the overtaking situation above is also needed.

Additional lanes at intersections

There are several problems with additional lanes at intersections. One has to do with the loss of space to the BL or WCL when additional turn lanes are provided with the same width of cross section. It is common practice now to use narrower lanes for turning movements or to calm traffic. Using narrower widths may retain the full width of the bike facility at the intersection.

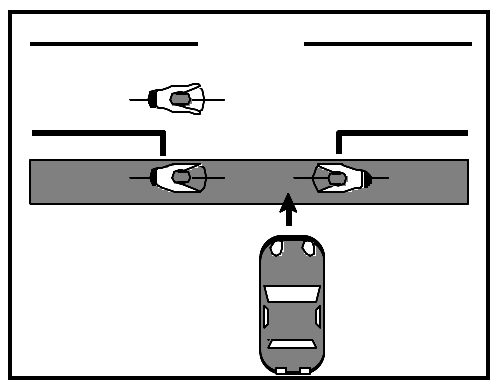


Figure 20. Typical conflict situations at a driveway crossing a sidewalk..

Another practice involves terminating either the BL or WCL and splitting the approaching traffic into two through lanes just prior to the intersection stop bar area. When this occurs, the two lanes often

Figure 22. Dashed BL stripe at right-turn situation.

become one again on the far side of the intersection (figure 21).
The idea is to use the extra lane to get traffic through the intersection faster, but with the notion comes problems for the bicyclist. First is the loss of space. Second is the weaving among the motorists as they jockey for position through the intersection and beyond as they must merge again.

Right turn lanes present another problem for bicyclists. There may be weaving between bicycles and motor vehicles in the approach to the right turn in a designated BL

Figure 23. European bike box.

if there is a high volume of right turning motor vehicle traffic. Use of a dashed stripe gives notice that weaving will take place (figure 22). Bicyclists may also have a tendency to overtake or stop on the right of motor vehicles turning right. Education on the hazards associated with this maneuver is recommended.

Whether right turn lanes are present or not, right turning motor vehicles at intersections pose a problem for bicyclists. Similar to the driveway conflict mentioned above, in the intersection area a motor vehicle may also turn right to another street

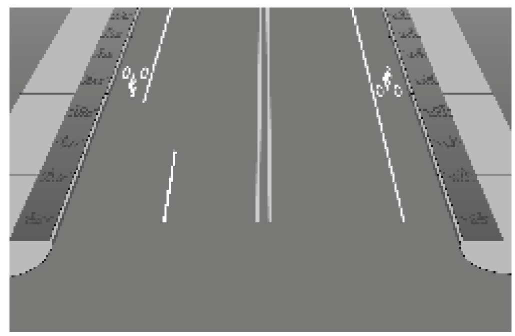


Figure 21. Example of traffic splitting.

soon after overtaking a bicyclist. One treatment made popular in Europe that helps to counter this problem is the use of an advanced stop bar or bike box (the term now frequently used to refer to this treatment in the United States). In Europe, a bike box is typically placed at the end of a BL (figure 23) so that bicyclists may proceed easily to the head of the traffic queue and thus get through the intersection ahead of right turning motor vehicle traffic. The bike box is gaining some popularity in the United States, and different versions of the technique are being tried or considered, such as placing a bike box at a WCL intersection, or using the bike box at a BL location to get left turning bicyclists to the head of the queue. The bike box appears to be well accepted in Europe. However, evaluations of such applications in the United States need to be made to determine if the applications are understood and accepted.

Conclusions

The debate over whether BLs or WCLs are preferable has been heated for many years. While both BLs and WCLs are acceptable facilities in many locations, the debate has sometimes forced decision makers to choose which facility type they prefer, to the exclusion of the other. More bicycle facilities might be in place in this country except for this long-standing division of opinion.

This comparative analysis of BL versus WCL sites utilized an extensive data base to examine many factors related to the operations and safety of these facilities. Forty-eight sites were videotaped in the study, and these produced 369 total conflicts, 276 of which were bike/motor vehicle conflicts. In reality this is relatively few conflicts, which is an encouraging outcome. On the other hand, approximately 6 percent of the bicyclists had a conflict with a motor vehicle, which is not a trivial amount. Many more sites would have been necessary to produce a wholesale increase in the number of conflicts available for analysis.

Across the board these facilities work well, with the vast majority of identified conflicts in this study being minor in nature. Both behavioral actions and geometric characteristics were identified as problems in the study of these bicycle facilities, and there are remedies for these, but in most cases the noted problems at the higher conflict rate sites could not be labeled as particular BL or WCL deficiencies. The destination patterns of bicyclists traveling through the project sites led to maneuvers and conflicts that in many cases would have occurred whether the bicycle facility present was *either* a BL or WCL.

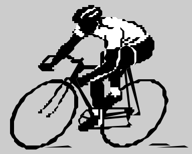
This is an important point that planners and engineers should heed. With their relative freedom of movement (i.e., not being as confined to a traffic lane as a motor vehicle), bicyclists will use a variety of ways to get through an intersection and on toward their destination. The chosen methods usually reflect perceived time savings/efficiency or improved safety. As an example, difficulties in making left turns because of heavy motor vehicle flows will likely lead to advance crossovers or other alternate maneuvers. Even though standard design templates for bicycle facilities should be applied wherever possible to promote consistency in understanding and proper movements through intersections, it is apparent that such templates cannot be applied across the board to achieve standard or desired bicyclist movements. Some tailoring will be necessary to take into account desired or frequent movements by bicyclists, just as is done for locations with high motor vehicle movements and/or crash rates.

The overall conclusion of this research is that *both* BL and WCL facilities can and should be used to improve riding conditions for bicyclists, and this should be viewed as a positive finding for the bicycling community. The identified differences in operations and conflicts were related to the specific destination patterns of bicyclists riding through the intersection areas studied. Given the stated preferences of bicyclists for BLs in prior surveys (e.g., Rodale Press, 1992), along with increased comfort level on BLs found in developing the Bicycle Compatibility Index (Harkey et al., 1998), use of this facility is recommended where there is adequate width, in that BLs are more likely to increase the amount of bicycling than WCLs. Increased bicycling is important because in the United States there are but a few communities that have a significant share of trips made by this mode. Overall, we have not yet reached the critical mass necessary to make motorists and pedestrians aware of the regular presence of the bicycle. When this critical level of bicycling is reached, gains in a "share the road" mentality will come much more quickly than at present. Certainly not all the problems will disappear, but the ability to develop and implement solutions will be greatly enhanced.

Appendix

A

Experience Form



Bicycle Facilities Evaluation Study - Exposure Data

Site ________________ and ________________ Data Collector Initials ________________

Site # ________ Day of Week __________ Start Time (24 hour) _________________

Date ____ / ____ / ____ Time 1 or 2 _____ End Time (24 hour) _________________

Obs. #	**Age**	**Days per Week**	**Miles per Week**	**Riding Experience** **1** **2**	**Where Riding** R=Road S=Sdwlk O=Other	**Race** W=White B=Black H=Hispan. A=Asian O=Other	**Sex** M= Male F= Fem	**Helmet Use** Y= Yes N= No O=Other	**Comments**

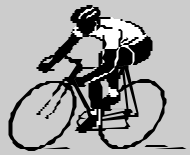
Survey Questions: *Enter ? if unknown or missing. Ask questions 1-4. Observe and record questions 5-8.*

1. What is your age? (record actual number years)
2. On average, how many days a week do you ride your bike? (record actual number of days, 0-7)
3. On average, about how many miles do you ride each week? (record actual number of miles reported)
4. How would you classify yourself with respect to the experience you have riding on city streets? (**1** or **2**)
5. Location where cyclist was riding (**R**oadway, **S**idewalk, **O**ther)
6. Race of cyclist (**W**hite, **B**lack, **H**ispanic, **A**sian, **O**ther or mixed)
7. Sex of cyclist (**M**ale, **F**emale)
8. Cyclist helmet use (**Y**es, **N**o, **O**ther)

Appendix

B

Coding Form



Coding Items for the Comparative Analysis of Bike Lanes versus Wide Curb Lanes (Task Order 7)

<u>General</u>

Date_____

Time of day data collected - inclusive ______

Use military time (e.g., 1200-1400 hours)

Tape time ________

Was bicyclist riding **wrong way**? (Has to be for some duration - not like a left turn)_____

1. Yes, in road
2. Yes, on sidewalk
3. No
4. Other ____

0. Unk.

If yes to riding wrong way, then code the 3 items below and then describe in a brief narrative any conflicts that resulted because of wrong way riding. Then skip to next screen for a new bicyclist.

<u>Bicyclist</u>

Bicyclist gender_____

1. Male
2. Female

0. Unsure

Bicyclist carrying passenger_____

1. Yes
2. No

0. Unsure

Bicyclist helmet use______

1. Yes
2. No

0. Unsure

Bicyclist Age______

1. <16
2. 16-24
3. 25-64
4. 65+

0. Unsure

Describe any **wrong way riding** conflicts____
____
____

Midblock (between 300-500 foot cones)

Bicyclist initial midblock position (i.e., at the 500 foot cone) _____
1. Bike Lane
2. Wide lane
3. Sidewalk
4. Path beside roadway
5. Traffic lane (e.g., lane next to bike lane or wide curb lane)
6. Other (e.g., weaving) ____
0. Unk.

Changed position midblock to______
1. Bike Lane
2. Wide lane
3. Sidewalk
4. Path beside roadway
5. Traffic lane (e.g., lane next to bike lane or wide curb lane)
6. Did not change positions
0. Unk.

Midblock movement_____
1. Straight to intersection
2. Left crossover in advance of intersection
3. Right in advance of intersection
4. Other ____
0. Unk.

Spacing and associated passing conditions (see list below) from curb or gutter pan seam to right side bike tire at approximate 500-foot cone ____/____ **(With no motor vehicle present, if possible)** To nearest tenth of a foot (e.g., 1.2 ft) - use transparency)

Associated passing conditions:
1. Bicycle alone and free flowing - **no** vehicle in vicinity(200-300 ft)
2. Bicycle alone and free flowing - vehicle in vicinity(200-300 ft)
3. Bicycle being passed by motor vehicle
4. Bike passing motor vehicles
5. Other (e.g., bike avoiding debris or other obstacle) _______________
0. Unk.

For any of the above conditions, was bike riding next to parked vehicles?
1. Yes
2. No

Spacing and associated passing conditions from first passing motor vehicle that can be viewed approximately between 300-500 foot cones
___/___ (Nearest tenth of a foot - left side bike tire to right side m.v. tire)
___/___ (Nearest tenth of a foot - from curb or joint to right side bike tire)

Did **motor vehicle** encroach into next lane when passing the bicyclist?____
1. Yes
2. No
0. Unsure

If yes, did this result in a motor vehicle to motor vehicle conflict?____
1. Yes
2. No
0. Unsure

Bicyclist midblock (between 300-500 foot cones) behavior ____/____/___ (Note: Use attached Behavior List. Code no more than 3 items. Also use this list for the coded behavior in midblock conflict coding below)

For the above bicyclist behavior, was there a vehicle in the vicinity — approximately 200-300 feet — (i.e., such that there was some chance for a conflict)?____
1. Yes
2. No
0. Unsure

Midblock Conflict No./Type___/____
Type 1= bike/motor vehicle
Type 2= bike/bike
Type 3= bike/pedestrian

For **midblock** conflict: Bike action_____ (Use attached behavior list. Try to code a single item. Use more codes if necessary.)
Motor vehicle action_____ (Use attached behavior list. Try to code a single item. Use more codes if necessary.)

Bicyclist level of avoidance response ______
1. No change in riding
2. Stops pedaling
3. Slight change of direction
4. Applies brakes
5. Major change of direction
6. Full stop
7. Collision or near crash
0. Unsure of response

Motor vehicle level of avoidance response ______
1. No change in driving
2. Slows
3. Slight change of direction
4. Applies brakes
5. Major change of direction
6. Full stop
7. Collision or near crash
0. Unsure of response

Seriousness of conflict ______
1. Minor (some braking or maneuvering to avoid each other, but there is time to do so)
2. Serious (braking or maneuvering that has to be done quickly to avoid contact)
0. Unsure

Describe any **midblock** conflicts____
____
____
____
____

Within Intersection (from 300-foot cone to intersection stop line/crosswalk)
Bicyclist initial **intersection** approach position____
1. Bike Lane
2. Wide lane
3. Sidewalk
4. Path beside roadway
5. Traffic lane (e.g., lane next to bike lane or wide curb lane)
6. Left turn lane
7. Right turn lane
8. Other ____
9. Never made it through intersection (If this, then skip following)
0. Unk.

Changed Intersection approach position to____
1. Bike Lane
2. Wide lane
3. Sidewalk
4. Path beside roadway
5. Traffic lane (e.g., lane next to bike lane or wide curb lane)
6. Left turn lane
7. Right turn lane
8. Other ____
9. Did not change positions
0. Unk.

Intersection movement____
1. Straight
2. Left
3. Right
4. U turn
5. Other ____
0. Unk.

Walked bike?____
1. Yes
2. No
0. Unk.

For **straight, left, or right** movement, **bicyclist** intersection traffic control____
1. Obeyed signal
2. Obeyed sign
3. Disobeyed signal
4. Disobeyed sign
5. Other____
6. Unsure

If disobeyed signal/sign____
1. Maneuver safe
2. Maneuver somewhat unsafe
3. Maneuver definitely unsafe
4. Other______________________________________
5. Unk.

Note: From here on, coder chooses between straight, left and right "sections." If straight, then ignore left and right, etc. Need good way to get screen cursor to shift if section n/a.

Bicyclist **straight** through method____
1. Straight through from bike lane to bike lane on other side of intersection
2. Bike lane to traffic lane
3. Wide lane to wide lane
4. Wide lane to other traffic lane
5. Like motor vehicle in traffic lane (i.e., using neither bike lane nor wide lane beginning the approach)
6. Stayed in street but crossed on marked crosswalk or crosswalk area
7. Moved to sidewalk and then to crosswalk area
8. Straight through from right turn lane
9. Other____
0. n.a./unk.

Straight method exit facility____
1. Bike Lane
2. Wide lane
3. Sidewalk
4. Path beside roadway
5. Traffic lane (e.g., lane next to bike lane or wide curb lane)
6. Other____
0. n.a./unk.

Tracking____
1. Straight
2. Shy to right
3. Shy to left (e.g., on one-way street)
0. Unk.

Bicyclist straight through intersection behavior___/____/___(Use attached list. Try to code a single item, but no more than 3.)

For the above **bicyclist** behavior, was there a vehicle in the vicinity — 200-300 feet — (i.e., such that there was some chance for a conflict)?____
1. Yes
2. No
0. Unsure

Straight through intersection Conflict No./Type___/____

Type 1= bike/motor vehicle
Type 2= bike/bike
Type 3= bike/pedestrian

For **straight** conflict: Bike action_____ (Use attached list. Try to code a single item. Use more codes if necessary.)
Motor vehicle action_____ (Use attached list. Try to code a single item. Use more codes if necessary.)

For **straight** conflict: **Motor vehicle** position ________
1. Same direction
2. Opposing direction
3. Cross street from left
4. Cross street from right
5. Other (e.g., driveway) ______________________________
0. Unk.

Bicyclist level of avoidance response ______

1. No change in riding
2. Stops pedaling
3. Slight change of direction
4. Applies brakes
5. Major change of direction
6. Full stop
7. Collision or near crash
0. Unsure of response

Motor vehicle level of avoidance response ______

1. No change in driving
2. Slows
3. Slight change of direction
4. Applies brakes
5. Major change of direction
6. Full stop
7. Collision or near crash
0. Unsure of response

Seriousness of conflict ______

1. Minor (some braking or maneuvering to avoid each other, but there is time to do so)
2. Serious (braking or maneuvering that has to be done quickly to avoid contact)
0. Unsure

Describe any **straight through** conflicts____
____
____
____

Bicyclist left turn method____

1. Motor vehicle style - proper destination positioning
2. Motor vehicle style - improper destination positioning
3. Pedestrian style - near side
4. Pedestrian style - far side
5. Right hook
6. Left turn from bike lane (new item)
7. Advance crossover
8. MV - Ped hybrid
9. Other/weird ____
0. n.a./unk.

Specify exit facility on left turn____
1. Bike Lane
2. Wide lane
3. Sidewalk
4. Path beside roadway
5. Traffic lane (e.g., lane next to bike lane or wide curb lane)
6. Unknown
0. n.a.

Merge distance for **bicyclist** making motor vehicle style left turn
Estimated distance from intersection stop line when bicyclist started merge to left (Use traffic cones to approximate) _____ (Nearest 10 feet)

If left turn like motor vehicle, was lane position correct/appropriate?____
1. Yes
2. No
0. Unsure

Bicyclist left turn intersection behavior___/___/____/ (Use attached list. Try to code a single item, but no more than 3.)

For the above **bicyclist** behavior, was there a vehicle in the vicinity (i.e., such that there was some chance for a conflict)?
1. Yes
2. No
0. Unsure

Left turn Conflict No./Type___/____
Type 1= bike/motor vehicle
Type 2= bike/bike
Type 3= bike/pedestrian

For **left turn** conflict: Bike action_____ (Use attached list. Try to code a single item. Use more codes if necessary.)
Motor vehicle action_____ (Use attached list. Try to code a single item. Use more codes if necessary.)

For **left turn** conflict: **Motor vehicle** position ________
1. Same direction
2. Opposing direction
3. Cross street from left
4. Cross street from right
5. Other (e.g., driveway) ____
0. Unk.

Bicyclist level of avoidance response ______
1. No change in riding
2. Stops pedaling
3. Slight change of direction
4. Applies brakes
5. Major change of direction
6. Full stop
7. Collision or near crash
0. Unsure of response

Motor vehicle level of avoidance response ______
1. No change in driving
2. Slows
3. Slight change of direction
4. Applies brakes
5. Major change of direction
6. Full stop
7. Collision or near crash
0. Unsure of response

Seriousness of conflict ______
1. Minor (some braking or maneuvering to avoid each other, but there is time to do so)
2. Serious (braking or maneuvering that has to be done quickly to avoid contact)
0. Unsure

Describe any **left turn** conflicts____
____
____
____
____

Bicyclist right turn method____
1. Done correctly (e.g., from bike lane or traffic lane to another bike lane or traffic lane)
2. Done incorrectly (e.g., from bike lane or traffic lane to wrong way position on cross street)
3. From bike lane or traffic lane to sidewalk
4. Weird ____
5. Unsure
6. n.a./unk.

Right turn exit facility____
1. Bike Lane
2. Wide lane
3. Sidewalk
4. Path beside roadway
5. Traffic lane (e.g., lane next to bike lane or wide curb lane)
6. Other____
0. n.a./unk.

Bicyclist right turn intersection behavior______(Use attached list. Try to code a single item. Use more codes if necessary.)

For the above bicyclist behavior, was there a vehicle in the vicinity (i.e., such that there was some chance for a conflict)?____

1. Yes
2. No
0. Unsure

Right turn Conflict No./Type___/____

Type 1= bike/motor vehicle
Type 2= bike/bike
Type 3= bike/pedestrian

For **right turn** conflict: Bike action_____ (Use attached list. Try to code a single item. Use more codes if necessary.)
Motor vehicle action_____ (Use attached list. Try to code a single item. Use more codes if necessary.)

For **right turn** conflict: Motor vehicle position ________

1. Same direction
2. Opposing direction
3. Cross street from left
4. Cross street from right
5. Other (e.g., driveway) ____
0. Unk.

Bicyclist level of avoidance response ______

1. No change in riding
2. Stops pedaling
3. Slight change of direction
4. Applies brakes
5. Major change of direction
6. Full stop
7. Collision or near crash
0. Unsure of response

Motor vehicle level of avoidance response ______

1. No change in driving
2. Slows
3. Slight change of direction
4. Applies brakes
5. Major change of direction
6. Full stop
7. Collision or near crash
0. Unsure of response

Seriousness of conflict ______

1. Minor (some braking or maneuvering to avoid each other, but there is time to do so)
2. Serious (braking or maneuvering that has to be done quickly to avoid contact)
0. Unsure

Describe any **right turn** conflicts____
____
____
____
____

For any **Additional Observations** to the movements through the intersection that should be mentioned, describe in a narrative ____
____
____
____
____

List of Behaviors

Bicycle/Motor Vehicle Common Actions

10. B/MV NONE
11. B/MV failed to stop at stop sign (Note: 11,12,13 include main & other intersections)
12. B/MV failed to stop at traffic signal; stopped but proceeded when gap
13. B/MV stopped at a controlled intersection but failed to yield
14. B/MV failed to yield at driveway or other uncontrolled midblock entrance/exit

15. B/MV improper left turn (turned left in front of approaching traffic)
16. B/MV improper right turn (swing wide) - *other than overtaking* (see 53)
17. B/MV failed to yield changing lanes/merging (*specific intent of changing lanes/merging*)
18. B/MV improper lane use (through from right, right from through, etc.)

19. B/MV slowed/stopped/swerved due to intersection traffic
20. B/MV slowed/stopped/swerved due to other traffic not influenced by the intersection (e.g., vehicle pulled off the road)

Motor Vehicle Initiated Events

50. MV traveling in bike lane/edge of wide curb lane (long term)
51. MV crowding (includes encroaching) bike lane, edge of travel lane
52. MV entered bike lane for right turn/failed to yield to cyclist
53. MV turned right in front of bicyclist after overtaking
54. MV (illegally) parked in bike lane/wide curb lane
55. MV entering/exiting on-street parking
56. MV driver or passenger entering/exiting a parked/stopped vehicle
57. MV other (describe) ____

Bicycle Initiated Events

80. B entering roadway from sidewalk/over curb
81. B turned or swerved across a lane of traffic
82. B passing slow or stopped vehicle on right in wide curb lane
83. B riding in-between slowed/stopped traffic
84. B crowding vehicles in travel lane
85. B stunt riding or other erratic riding (Note: Only code 84, 85 if mv nearby)
86. B riding 2+ abreast (only if causes conflict)
87. B lost control due to curb face or gutter seam
88. B lost control due to other surface irregularity or debris in road
89. B lost control - other or unknown cause
90. B encounter with pedestrian
91. B encounter with another bicyclist
92. B other (describe) ____

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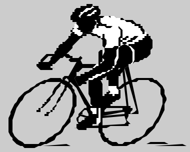

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